A STUDY OF PRESSURE-VOLUME RATES AND PLENUM MEMBRANE ADDITIONS TO THE CAPTURED AIR BUBBLE SURFACE EFFECT SHIP XR-3 DIGITAL COMPUTER LOADS AND MOTION PROGRAM

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THESIS

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by

John Martin Boggio

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I. INTRODUCTION

A. BACKGROUND

The Captured Air Bubble Surface Effect Ship (CAB SES) offers a dynamic new approach to improve surface ship performance. As with any new approach, extensive testing at the design stage of development is required. The U.S. Navy has been conducting sea trials on two 100 ton Captured Air Bubble (CAB) test craft, the 100-A and the 100-B [Ref. 1]. In addition to scale model testing, another approach to design evaluation involves the use of high speed digital computers to simulate the dynamic performance of the craft.

A digital computer Loads and Motion (L&M) program for the CAB SES was developed under government contract by the Oceanics Corp. [Ref. 2]. The L&M program installed at the Naval Postgraduate School, W. R. Church, computer facility on an IBM 360/67 computer was for a 100 ton displacement test craft, the 100-B. Leo and Boncal [Ref. 3] modified this computer program to represent a smaller 3 ton craft, the XR-3. The XR-3 is an operational test craft currently maintained and operated by the Naval Postgraduate School [Ref. 4].

Various modifications and changes to Leo and Boncal's basic work have been implemented. Finley, Forbes, and Menzel, in Refs. 5-7, provides program changes to obtain better representation of the Fan maps, bow and stern seal dynamics and pitch and roll damping.

One adverse characteristic of both the 100-B computer program and the XR-3 computer program was the extensive use of the digital computer time when operating in simulated sea states. Since the 100-B and the XR-3 programs are similiar, the computer time analysis provided by Mitchell [Ref. 8] for the 100-B also applies to the XR-3 program.

Another aid to design is the testing done in towing tanks in which scale models are used. Towing tests were conducted at NSRDC using a rubber membrane installed on the forward portion of a CAB SES model in order to better scale the pressure-volume relationship [Ref. 9]. The addition of this membrane improved the pitch and heave characteristics of the scale model in sea state operation.

B. OBJECTIVES

It is the objective of this work to examine the L&M digital computer program and make any changes that would improve the program with particular attention to changes that would reduce the amount of time required to execute the program.

A second objective is to model the plenum membrane, add the required program changes and study the effects of the membrane on simulated craft performance.

II. PROGRAMMING CHANGES

A. RATE EQUATIONS FOR PRESSURE AND VOLUME

1. Introduction

An examination of the dynamics of the XR-3 L&M program indicate that the key parameters of this type of ship design are those which describe the dynamic behavior of the bubble of the air in the plenum. This pressure of air provides approximately 75% of the lift force when the craft is "on the bubble." Small changes in bubble volume and pressure therefore cause significant changes in total ship response. These variables were examined in an effort to decrease the digital computer simulation execution time.

2. SUBROUTINES RHS and INTGRL

The force and moment equations for the craft are the six degrees of freedom equations plus four auxillary equations contained in SUBROUTINE RHS [Ref. 2].

The integration of these equations is performed in SUBROUTINE INTGRL. INTGRL uses the Runga-Knutta-Merson numerical integration technique with an automatic variable step size. If the error tolerances specified are exceeded the step size is reduced and the step repeated until all error tolerances are met or the step size is reduced to 1×10^{-6} sec., at which point the program stops. Thus the integration values are forced to converge to their correct values. All ten equations are integrated serially at the

same time step. When all integration error tolerances are met INTGRL returns the integrated values and increases the simulation time one time-step increment. Since pressure and volume are key variables, integrating their rates should cause the system of equations to converge more rapidly to their true values and avoid any problems associated with the feedback loops in the pressure-volume calculation [Ref. 10].

3. Formulation of Volume Rate and Pressure Rate

The bubble pressure equation is for an adiabatic process [Ref. 2].

$$P_b = P_a \left(\frac{\rho_b}{\rho_a} \right)^{\gamma} \tag{1}$$

where the subscripts a and b represent atmosphere and plenum values respectively

P = pressure absolute

$$\rho = \text{density } \frac{M}{V} \tag{2}$$

γ = adiabatic exponent for air

Substituting (2) into (1)

$$P_b = P_a \left(\frac{M}{V\rho_a} \right)^{\gamma} \tag{3}$$

Differentiating (3) with respect to time where P_a and ρ_a are assumed to be constant yields

$$\dot{P}_b = \frac{P_a}{\rho_a} \gamma \left(\frac{M}{V\rho_a} \right)^{\gamma-1} \left(\frac{V\dot{M} - M\dot{V}}{V^2} \right) \tag{4}$$

Factoring $\frac{M}{V}$ from the last term of (4)

$$\dot{P}_b = \gamma P_a \left(\frac{M}{\rho_a V}\right)^{\gamma-1} \left(\frac{M}{\rho_a V}\right) \left(\frac{\dot{M}}{M} - \frac{\dot{V}}{V}\right) \tag{5}$$

Noting $\left(\frac{M}{\rho_a V}\right)^{\gamma-1} \left(\frac{M}{\rho_a V}\right) = \left(\frac{M}{\rho_a V}\right)^{\gamma}$

and

$$P_a \left(\frac{M}{\rho_a V}\right)^{\gamma} = P_b$$

$$\dot{P}_b = \gamma P_b \left(\frac{\dot{M}}{M} - \frac{\dot{V}}{V}\right) \tag{6}$$

The volume equation for the bubble is computed in RHS in four parts and summed together

$$V = Vnom - D - WA + WT \tag{7}$$

The four terms that determine volume are

(1) Vnom = the empty plenum volume

(2) D = draft term-change in volume due to draft

(3) WA = Wave term-change in volume due to the presence of waves

(4) WT = WATSLP term-- correction term for the added volume wedge which is a function of speed [Ref. 6].

Differentiating equation (4)

$$\dot{V} = -\dot{D} - \dot{WA} \tag{8}$$

where

$\dot{WA}$ = rate of change of volume due to waves

$\dot{D}$ = rate of change of volume due to displacement

$\dot{WT}$ = 0.0

$\dot{V}nom$ = 0.0

$\dot{WA}$ is computed in SUBROUTINE WAVES by taking the difference in change of volume due to waves at successive time steps and dividing by the time step. Since WATSLP is a function of speed, the differentiated value of WATSLP, $\dot{WT}$, is a function of acceleration. Forward accelerations are normally small; therefore, the differentiated value of WATSLP was approximated to be zero. Equations (4) and (5) were programmed as follows:

```
VALUE (11) = -(((XL*WIDTH)-ABW)*.5*W)-DVWDOT
VALUE (12) = GAM*VAL(13)*(VALUE(10)/VAL(11)-VALUE(11)/
              VAL(12))
```

where

DVWDOT = rate of change of volume due to waves

VALUE(10) = Bubble mass flow rate

VALUE(11) = Volume rate

VALUE(12) = Pressure rate

VAL(11) = Bubble Mass

VAL(12) = Bubble Volume

VAL(13) = Bubble Pressure

GAM = Adiabatic Exponent for air

B. ELIMINATION OF SUBROUTINE DMINV

In an effort to improve program timing, the suggestions given in Ref. 7 were undertaken. One recommendation suggested the removal of SUBROUTINE DMINV in the 100B L&M program by making changes to SUBROUTINES INCON and RHS. An examination of the L&M program indicated that these changes also could be applied to the XR-3 program. Consequently the following was deleted:

```
212   DO 211 I = 1,6
      DO 211 N = 1,6
211   A(I,N)    = 0.0
      DO 213 N = 1.3
213   A(N,N)    = AM
      A(4,4)    = AIXX
      A(5,5)    = AIYY
      A(6,6)    = AIZZ
      A(4,6)    = -AIXZ
      A(6,4)    = -AIXZ
      AIMAX     = AMAXI(AM, AIXX,AIYY,AIZZ,ABS(AIXZ))
      DO 214 I = 1,6
      DO 214 J = 1,6
214   A(I,J)    = A(I,J)/AIMAX
      CALL DMINV(A,G,D,)
      DO 215I   = 1,6
215   A(I,J)    = A(I,J)/AIMAX
      IF (D.NE.0.0.) GO TO 10
      WRITE (6,216)
      STOP
```

In place of the above the following was added:

```
215   AMASSI = 1.0/AM
      D      = 1.0/(AIXX*AIZZ-AIXZ*AIXZ)
      DIXX   = AIXX*D
      DIXZ   = AIZZ*D
      DIZZ   = AIZZ*D
      AIYYI  = 1.0/AIYY
      GO TO 10
```

Linkage between INCON and RHS was provided by the following

```
COMMON/ATRIX/AMASSI,AIYYI,DIXX,DIXZ,DIZZ
```

In SUBROUTINE RHS the six element matrix GF(J) was deleted and the following identifiers were substituted for the summation of forces: SUMX, SUMY, SUMZ, SUMK, SUMM, SUMN. In addition, the following deletion was made.

```
DO 1 I = 1,6
VALUE(I) = 0.0
DO 1 J = 1,6
VALUE (I) = VALUE (I) + A(I,J)*GF(J)
1 CONTINUE
```

Substituted for the above DO LOOPS was the following

```
VALUE (1)  = SUMX*AMASSI
VALUE (2)  = SUMY*AMASSI -R*U
VALUE (3)  = SUMZ*AMASSI
VALUE (4)  = SUMK*DIZZ + SUMN*DIXZ
```

VALUE (5) = SUMM*AIYYI

VALUE (6) = SUMN*DIXX + SUMK*DIXZ

These changes eliminated SUBROUTINE DMINV and several DO LOOPS.

C. EXPANSION OF WAVE COMPONENTS

Since the program was being tested with sea state, the method used for the wave generation was studied. SUBROUTINE INCON provides a means of introducing sea-state by individual wave components and amplitudes. In addition, the subroutine will accept an average height and lowest and highest wave frequency and/or wave period and generate up to 10 wave components.

These wave components represent a sampling of the spectural energy density of the given sea state condition. Reference 11 suggests for irregular sea, a minimum of 15 - 20 components are required to simulate irregular sea conditions. The program dimension statements were accordingly increased from 10-20 to determine if any significant changes could be observed by increasing the number of wave components.

D. MISCELLANEOUS

Each subroutine was examined with regard to efficiency of coding and changes were implemented such as multiplication in lieu of the use of the exponential. For example, IBM 360/67 fixed point exponentiation requires that the natural logarithm be generated and then a logarithm be computed, as compared

to straight forward multiplication. When such exponentiation is nested in DO LOOPS, a significant time savings can be realized by the use of multiplication.

III. TEST PRODECURES

A. COMPUTER SYSTEM

The digital computer used throughout this study is an IBM 360/67 model, VERSION I, located at the NPS W. R. Church Computer Facility. The system's hardware configuration provides 2 M bytes of core. This main core is composed of IBM core storage devices (IBM 2365 Mod. 12) and compatable but slightly different Lockheed core storage devices (MM 365). The Lockheed core devices are about 18% slower in execution time than IBM core devices. Since the system is time-shared and the core is contiguous, there is no practical way to determine in which portion of the main core the program is residing. Therefore, exact timing of a program is not easily achieved. In this report all timing values must be interpreted with this anomaly in mind. Among the options available under this operating system are the FORTRAM G and FORTRAN H compilers [Ref. 12]. Mitchell reported substantial time savings using the H compiler [Ref. 8]. Since one of the main objectives was to reduce execution time, computer model testing was done using both compiler options. Runs made under different compilers will be noted.

A word of caution on the use of the H compiler. The H compiler produces its timing improvements and core reduction by coding optimization. This means the compiler re-arranges

the Fortran code. This re-arrangement may move computations outside of DO LOOPS for example. Applicable portions of Ref. 13 should be read and understood before using this feature.

B. TEST CONDITIONS

The L&M program for the XR-3 used in this report is the one given in Ref. 7. This program was then modified to incorporate the changes previously described. The basic program [Ref. 7] computes pressure using eq. (1) and volume using eq. (7) and is referred to as PROGRAM ONE. PROGRAM ONE was used as reference for comparative purposes. The addition of the pressure rate and volume rate equations (6) and (8) and the elimination of SUBROUTINE DMINV constituted major modifications to the basic program. This version of the Loads and Motion program was called PROGRAM TWO. PROGRAM THREE was PROGRAM TWO compiled and executed with the FORTRAN H compiler.

Five test conditions for a given speed were established to provide a full range of disturbances for testing the L&M programs. These test conditions are tabulated in Table I.

In Condition One small disturbances were introduced by changing the initial conditions of draft (DS) and pitch (θ). These changes consisted of decreasing the draft and pitch from previously computed steady state values by the magnitude shown in Table I. In addition, the rudder was held at zero and the sea was calm. In Condition Two, the perturbations were the same as Condition One except that now the rudder

TABLE I

TEST PERTURBATIONS

	Δ DS	$\Delta\theta$	RUDDER	SEA STATE
Condition One	0.1 inch	.03	0.0	Calm water
Condition Two	0.1	.03	20°	Calm water
Condition Three	0.0	0.0	0.0	Regular One
Condition Four	0.0	0.0	0.0	Regular Two
Condition Five	0.0	0.0	0.0	Irregular One

was displaced to the right 20 degrees. The rudder was offset at the start of the simulation and held through the run as this value. In Condition Three, Four and Five the only disturbances used were the sea state conditions.

Sea state is generated in SUBROUTINE WAVES. SUBROUTINE INCON generates wave components and amplitudes based on several different type input parameters. [See users manual Ref. 7]. Regular sea one and two are simple sinusoidal waves. Irregular sea state conditions are simulated by the addition of several regular sinusoidal wave components. Sea state used throughout this study is true sea state and is not scaled in any manner.

The L&M program provides two options for propulsion, either constant speed or constant thrust. The constant

thrust option was selected because this is the normal operating mode for the XR-3 test craft.

Integrator tolerance levels were maintained at the values given in Ref. 7. However two new error tolerances had to be determined for the integration of the pressure and volume rates. These new levels were determined by first selecting a very tight value .000001 which was increased in increments until a change in output could be noticed. The value was then decreased by a factor of 10. Pressure and volume tolerance levels were then set at this value which was found to be .0001.

All other variables such as draft and pressure were initialized from the steady state undisturbed conditions for that specific starting speed. The steady state conditions were evaluated by first using the constant speed propulsion option and the initial values in Ref. 7. The program was then run until the key input variables - pitch, draft, thrust and pressure - reached steady state. These values were then read in and propulsion was switched to constant thrust. The program was run again to insure that steady state conditions existed. These steady state values are shown in Table II.

TABLE II

STEADY STATE CONDITIONS

Speed(Knots)	10	20	30
Pressure	23.93	24.84	24.84
Draft	8.17	6.12	5.34
Thrust (each engine)	200.31	218.17	287.22
Pitch	1.62	.48	.26

Pressure in psfg

Draft in inches

Thrust in ft. lb.

Pitch in degrees

IV. MEMBRANE ADDITION

A. INTRODUCTION

During towing tank tests conducted at NSRDC, a rubber membrane was installed on the forward bow of the XR-1 scale model [Ref. 9]. The installation of this membrane improved the pitch and heave characteristics of the scale model during simulated sea conditions. Reference 9 provided the following emperical expression which relates the Pressure and Volume of the membrane.

$$V = KP_b \tag{9}$$

K was experimentally determined and has the value .317 when scaled to the XR-3 test craft dimensions. (See Appendix A).

B. MATHEMATICAL MODELING

The approach used to include the effects of this membrane was to develop mathematical expressions which could be added to the already existing pressure, volume and air mass equations in the L&M program. Five mathematical expressions were developed, tested and referred to as Models One, Two, Three, Four and Five. They are explained below and the results discussed in Section V.

1. Model One

Model One is based on the premise that by correcting the plenum volume with the membrane volume, the equations

in SUBROUTINE RHS would show the effect of the membrane. Model One added the following equation to PROGRAM ONE;

$$V_m = K\ P_m \tag{10}$$

Then using (10) to correct the volume of the plenum and assuming $P_m = P_b$.

$$V = V_b + V_m \tag{11}$$

where V_b is given by eq. (7).

2. Model Two

Model Two is an extension of Model One. Based on the premise that by correcting the rate of change of plenum volume with the rate of change of membrane volume, the rate equations given in SUBROUTINE RHS and subsequent integration of these terms would show the effect of the membrane. Model Two added the following rate equation to PROGRAM TWO.

$$\dot{V}_m = K\ \dot{P}_m \tag{12}$$

Then using (12) to correct the rate of change of plenum volume and assuming

$$\dot{P}_m = \dot{P}_b$$

$$\dot{V} = \dot{V}_b + \dot{V}_m$$

where $\dot{V}_b$ is given by eq. (8).

3. Model Three

Model Three was based on the premise that the volume rate eq. (8) and the pressure rate eq. (6) as computed without the membrane could be corrected for the membrane by adjusting these terms by appropriate factors within PROGRAM TWO.

Correction terms were sought that would be a function of the membrane. A logical candidate for this correction factor for the pressure was the ratio of rates of change of the membrane volume to plenum volume multiplied by plenum pressure rate.

$$PCT = \frac{\dot{V}_m}{\dot{V}_b} \dot{P}_b \tag{13}$$

where PCT is the correction factor to be added to the plenum pressure rate term $\dot{P}_b$ before integration. It was assumed that the pressure and pressure rate of the plenum and membrane were equal.

$$P_m = P_b \tag{14}$$

$$\dot{P}_m = \dot{P}_b \tag{15}$$

It was also assumed that the membrane volume rate and pressure rate were related by

$$\dot{V}_m = K\dot{P}_m \tag{16}$$

Substituting (16) into (13) and using (15)

$$PCT = K \frac{\dot{P}_b^{\,2}}{\dot{V}_b} \tag{17}$$

The volume rate correction term was assumed to be the ratio of the rate of change of membrane pressure to the rate of change of plenum pressure times the rate of change of membrane volume.

$$VCT = \frac{\dot{P}_m}{\dot{P}_b} \quad \dot{V}_m \tag{18}$$

where VCT is the correction factor to be added to the plenum volume rate term $\dot{V}_b$ before integration

Since $\dot{P}_m = \dot{P}_b$ and $\dot{V}_m = K\dot{P}_b$

Then from (18)

$$VCT = K\ \dot{P}_b \tag{19}$$

Then using equations (17) and (19) the rate equations are

$$\dot{V} = \dot{V}_b + VCT \tag{20}$$

$$\dot{P} = \dot{P}_b + PCT \tag{21}$$

where $\dot{V}_b$ is given by eq. (8) and $\dot{P}_b$ by eq. (6).

Consider the following. Since K is a function of the elasticity of the membrane, if K = 0.0. Equations (20) and (21) reduce to the no membrane case.

If the membrane expands at the same rate that the volume of the plenum contracts the system volume rates is zero and the system pressure rate is also zero.

4. Model Four

Again using PROGRAM TWO, Model Four was based on the premise that the mass of the membrane air and mass flow rate of membrane air would be important factors in any correction term to be applied to plenum volume rate and pressure rate.

Again it was assumed that the membrane effect could be described as an adiabatic reversible process. Then using Equation (6) applied to the membrane,

$$\dot{P}_m = P_m \gamma \left(\frac{\dot{M}_m}{M_m} - \frac{\dot{V}_m}{V_m} \right) \tag{22}$$

where m denotes membrane

$\dot{M}_m$ = Mass flow rate of the membrane air

M_m = Mass of the membrane air

Again it was assumed that the pressure and pressure rate of the membrane and plenum were equal.

$$P_m = P_b \tag{23}$$

$$\dot{P}_m = \dot{P}_b \tag{24}$$

It was also assumed that the membrane volume rate and pressure rate were related by

$$\dot{V}_m = K \dot{P}_m \tag{25}$$

Equation (25) was obtained by differentiating

$$V_m = K P_m \tag{26}$$

Substituting (25) and (26) into (22) yields

$$\frac{\dot{M}_m}{M_m} = \left(\frac{1+\gamma}{\gamma} \right) \frac{\dot{P}_m}{P_m} \tag{27}$$

One term is not available, M_m. Two possibilities were considered to determine this value. The first possibility would be to integrate $\dot{M}_m$ and use the result of the integration from the preceding time step. The other possibility would be to hold temperatures constant in the membrane, and use the ideal gas law to determine M_m for varying pressure and volume. This last condition would be in error; however, as a first approximation, it would produce acceptable results.

Because of the past history of difficulty with integrator 10, plenum air mass rate, the second possibility was chosen. Evaluation of the terms in the ideal gas law for a temperature of 68^o degrees excluding mass, pressure and volume produced the constant.

$$4.9 \times 10^{-7} \text{ slugs/psf - ft}^3$$

therefore;

$$M_m = (4.9 \times 10^{-7}) (P_m)(V_m) \qquad (28)$$

Equations (22), (25) and (27) describe the membrane. These equations are used to correct the mass rate and volume rate of the plenum without the membrane.

$$\dot{M}_s = \dot{M} + \dot{M}_m \qquad (29)$$

$$\dot{V}_s = \dot{V} + \dot{V}_m \qquad (30)$$

where

s = denotes the system of plenum plus membrane

$\dot{M}$ = mass flow rate of plenum

$\dot{V}$ = volume rate of change of plenum

Using (29) and (30) in equation (6) the corrected plenum pressure rate is

$$\dot{P}_s = P_b \gamma \left(\frac{\dot{M}_s}{M} - \frac{\dot{V}_s}{V} \right)$$

where P_b, M and V are values obtained from the previous time-step calculation.

5. Model Five

Model Five is the application of equation (10) to PROGRAM TWO. It is based on the premise that the volume of the membrane could be introduced into the plenum pressure rate equation, and represent the membrane effect.

$$V_m = K\ P_m \tag{31}$$

$$V = V_b + V_m \tag{32}$$

Equation (31) and (32) are computed as in Model One. Then equation (32) is used in the pressure rate equation.

$$\dot{P} = P_b \gamma \left(\frac{\dot{M}}{M} - \frac{\dot{V}}{V} \right) \tag{33}$$

V. DISCUSSION OF RESULTS

A. PRESSURE RATE AND VOLUME RATE CHANGE

The addition of the pressure rate and volume rate equations was implemented without any major difficulty. In order to provide a basis of comparison for computer time analysis a quality factor "Q" was established. "Q" is defined to be the ratio of CPU execution time to problem time. For example, if the problem specified 1 minute of simulation and the CPU execution time (GO STEP in IBM COMPUTER SYSTEMS) was 5 minutes Q = 5.0. PROGRAMS ONE, TWO and THREE were tested with identical input parameters. The results are summarized in Table III and Table IV.

Runs were compared using PROGRAM ONE as a reference. No differences in computed output were noted for Condition One thru Four and only small changes in computed values noted with Condition Five. The integrator error tolerance levels were maintained constant for all runs.

As can be seen from the tabulated values, the addition of pressure rate and volume rate equations reduces the CPU execution time considerably for small disturbances. However, as the sea state is increased the CPU time increases. Apparently other factors in the program begin to dominate the total execution time.

TABLE III

TIMING QUALITY FACTORS

20 Knots

	Program One	Program Two	Program Three
Condition One	11.25	4.8	4.50
Condition Two	13.85	6.0	5.50
Condition Three	23.0	20.5	19.2
Condition Four	42.8	28.01	22.0
Condition Five	71.0	58.1	54.0

TABLE IV

TIMING QUALITY FACTORS

30 Knots

	Program One	Program Two	Program Three
Condition One	10.8	7.5	4.5
Condition Two	18.0	14.25	8.7
Condition Three	24.0	22.0	21.0
Condition Four	45.0	30.0	28.0
Condition Five	75.0	59.2	53.0

This supports the results of Reference (7) that for sea conditions the bulk of computation time is apparently in the SUBROUTINE WAVES.

It was observed that at irregular sea state two and regular sea state three water came in contact with the top of the plenum. The L&M program does not include the effect of this phenomenon in the program simulation; therefore, testing was not conducted at higher sea state conditions. The fact that water hits the top of the plenum is a reasonable condition under certain circumstances. For example, if the pitch angle is 3 degrees up the stern sinks over 6 inches. If the draft of the craft at that time is 11 inches and if the preceding wave passing the stern station is 5 inches, water should hit the top of the plenum at the stern station. The effect of this condition on total craft behavior in terms of forces and moments is not known. The effect of water contact would depend upon such factors as the length of time the wave is in contact with the top of the plenum and the area of the plenum in contact with the wave.

B. INCREASING WAVE COMPONENTS

Tests were made for irregular seas one and two using 8, 10, 15, and 20 wave components. No apparent change in output could be determined. The time at which changes in output occurred changed, but no significant reduction in output values were noted; that is the time when wave components were in-phase or out-of-phase was different, but the craft response

was the same. It was felt that if more components were used, the energy (in this case, the magnitude and frequency of the disturbing force) would be distributed over many components and that the irregular combination of these components would spread the energy of the disturbance over a larger time base. This spreading of the energy would then reduce the magnitude of the disturbance and that in turn would provide less rapid rates of change. With less rapid changes in the disturbances, the integration would take less time. The over-all time increase due to more wave components would be offset by the reduction in integration time. This is not the case; using more wave components increased CPU time. Whether 10 or less wave components are sufficient to accurately represent irregular seas was not tested.

C. MEMBRANE MODELS

A large amount of time was expended in attempting to provide adquate modeling of the plenum membrane. Model One using $V_m = K\ P_b$ in PROGRAM ONE did not work at all. The program would begin to execute and then stop when the integration step size was less than 1×10^{-6}.

As an aid to find the reason for this failure a computational flow diagram was drawn (See Figure 1). The addition of the correction term V_m creates an algebraic inner loop as shown by the dashed line in Fig. 1. Using a small perturbation of D in calm water and using the print switches in RHS as well as using the DEBUG option available with the G compiler, it

was observed that with Model One the values of pressure were divergent. It is not known why pressure values diverge; however, it was noted that at certain times the values of pressure and volume were increasing or decreasing together, that is when pressure was increasing while volume was increasing.

The computational flow diagram for Model Two (Figure 2) shows the inner connections of the pressure, volume and mass variables. Model Two exhibited the same symptoms and the same results as Model One, except in some cases pressure rate and volume rate rose or fell together at the same time step.

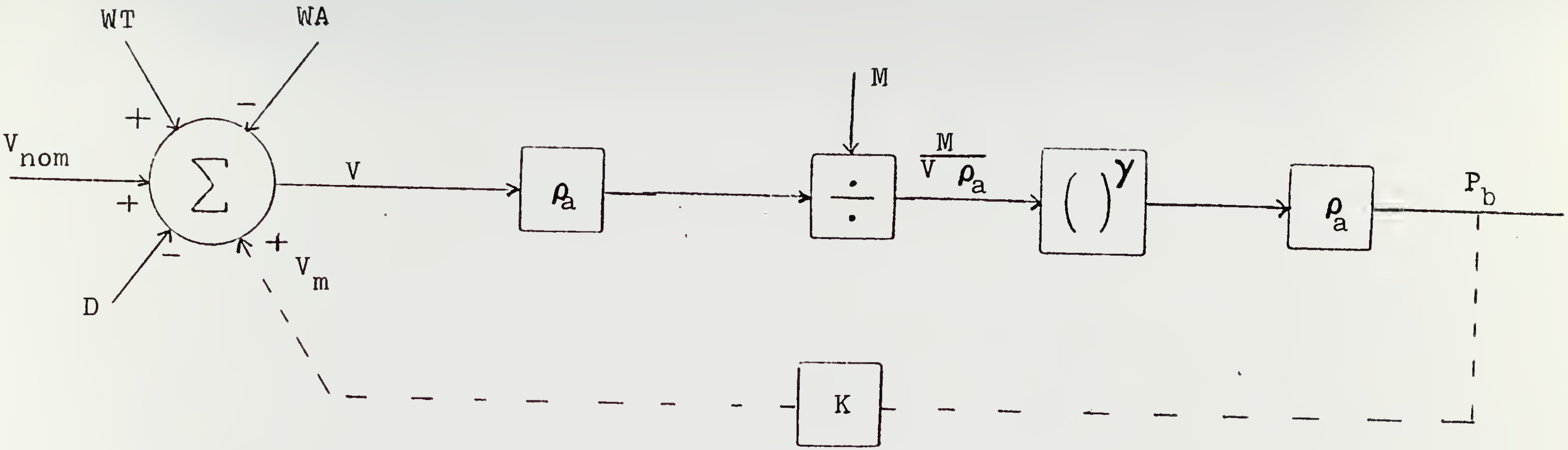
The failures of Model One and Two led to Model Three. It was felt that by correcting both pressure rate and volume rate the divergence exhibited in Models One and Two could be corrected. Model Three also failed; however, it provided the motivation to consider mass rate into the membrane. The computations performed in Model Three is shown in Figure 3.

Model Four was marginally successful. The program executes and slightly reduces the center of gravity acceleration. the reduction of the center of gravity acceleration was chosen as the criterion of whether the model was representing the membrane. This model was tested in sea state one and sea state two and provides slight reduction in the maximum values in the center of gravity acceleration. It did not reduce all of the center of gravity values. The computational flow diagram

of Model Four is given in Figure 4 and shows no algebraic loops in the RHS computations of pressure and volume rates.

Model Five was the most successful model. The computational flow is shown in Figure 5. Model Five reduced the center of gravity acceleration and for small disturbances, the pitch angle and pitch rate. For sea state one a significant reduction was observed. (See Figures 6 and 7). However, for sea state two the center of gravity accelerations were greater for the membrane when compared to the no membrane case. (See Figures 8 and 9). No reason for this could be found. The only differences in these two runs was the sea state.

One possible reason for the sea state two results, though not yet proven, could be a resonance effect at the sea state encounter frequency. Concurrent work in this area [Ref. 14] investigates the conditions for the existence of any resonance phenomena. Preliminary investigations indicate that at a wave encounter frequency of approximately 4 rad / second resonance in pitch angle occurs. The encounter frequency for regular sea state two is 5 rad / second. Whether resonance phenomena could cause this effect, however, was not determined.



(All values shown for the K^{th} iteration in RHS)

Figure 1. Computational Flow Diagram Model I

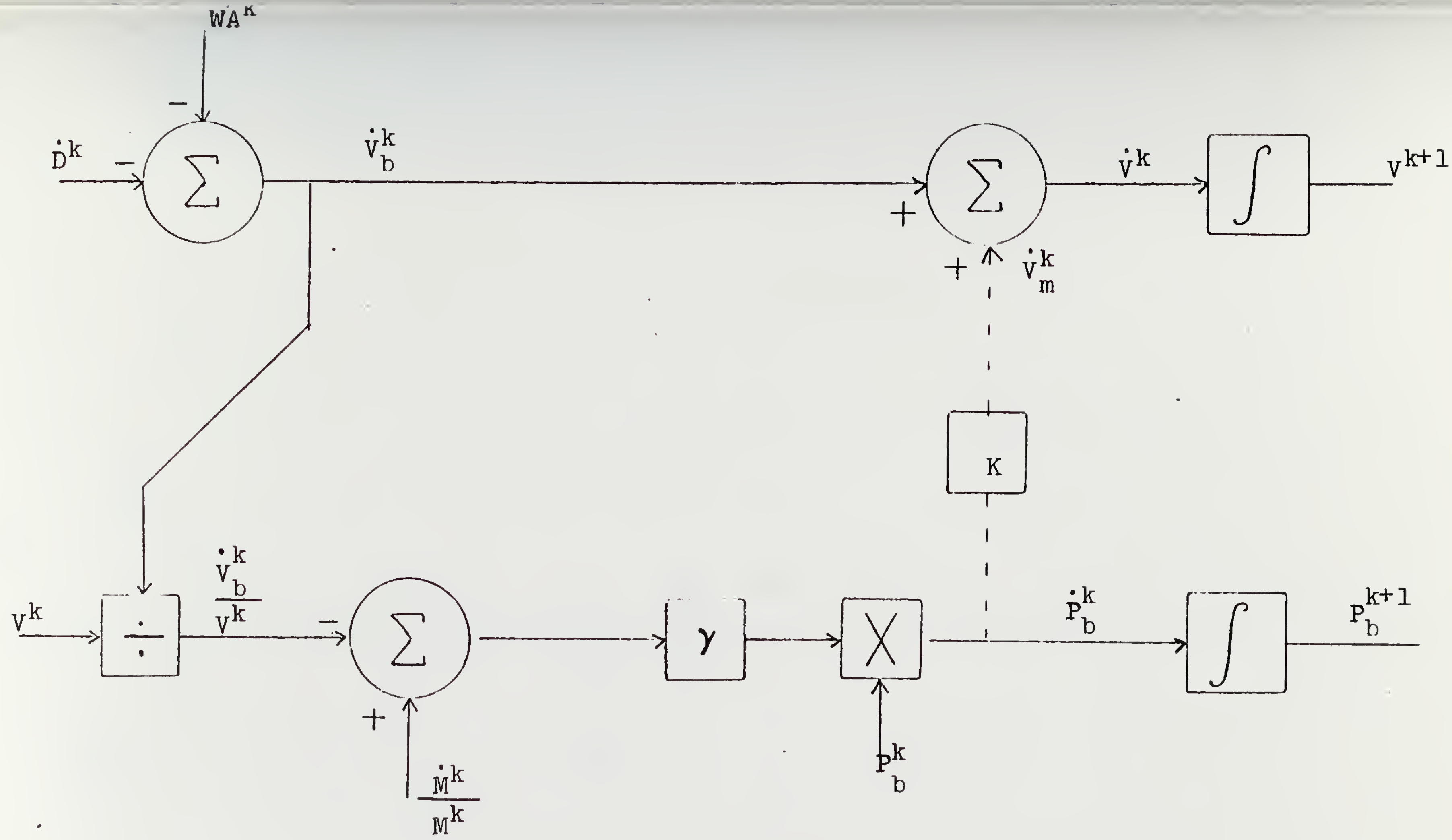


Figure 2. Computational Flow Diagram Model II

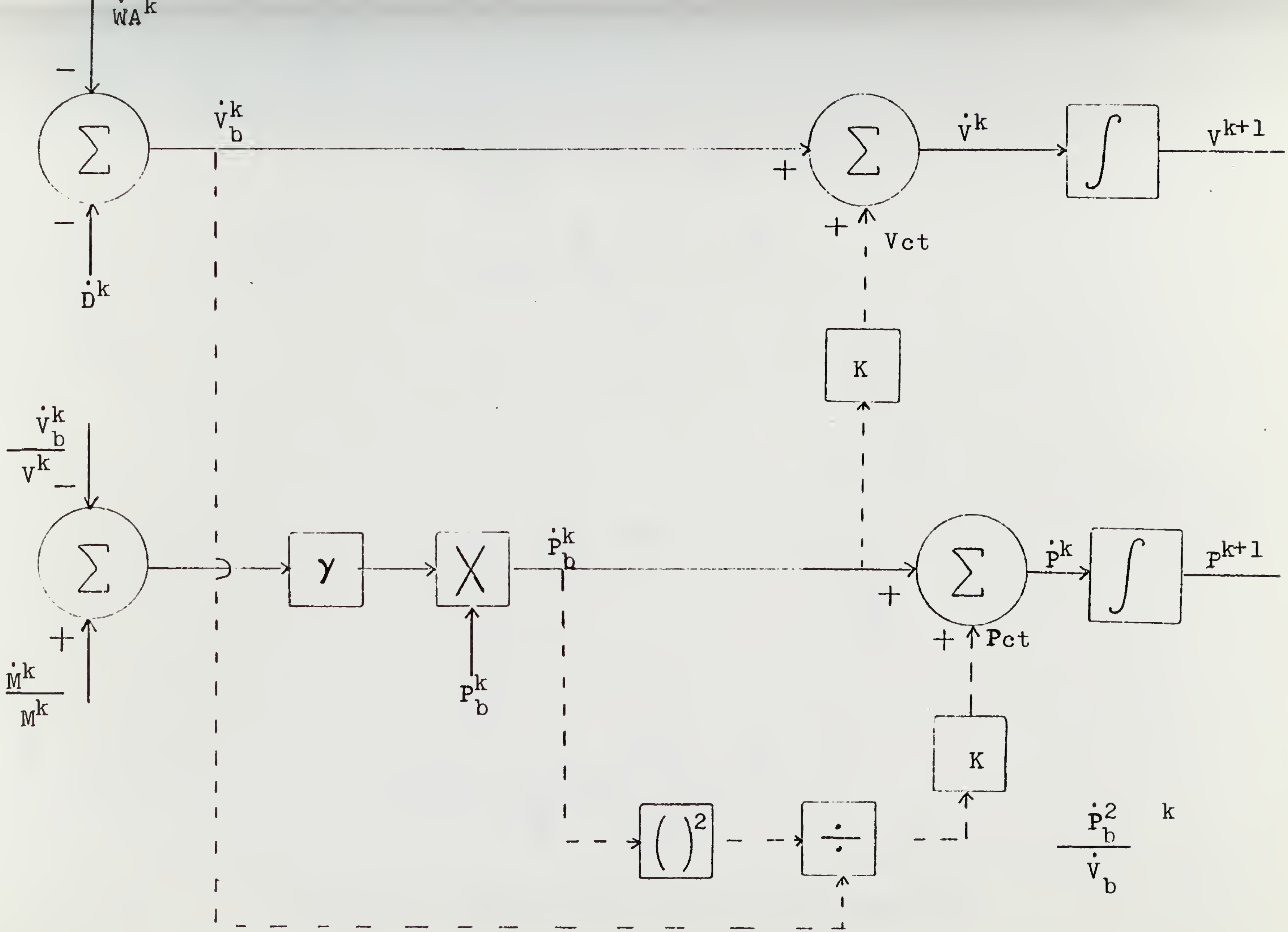


Figure 3. Computational Flow Diagram Model III

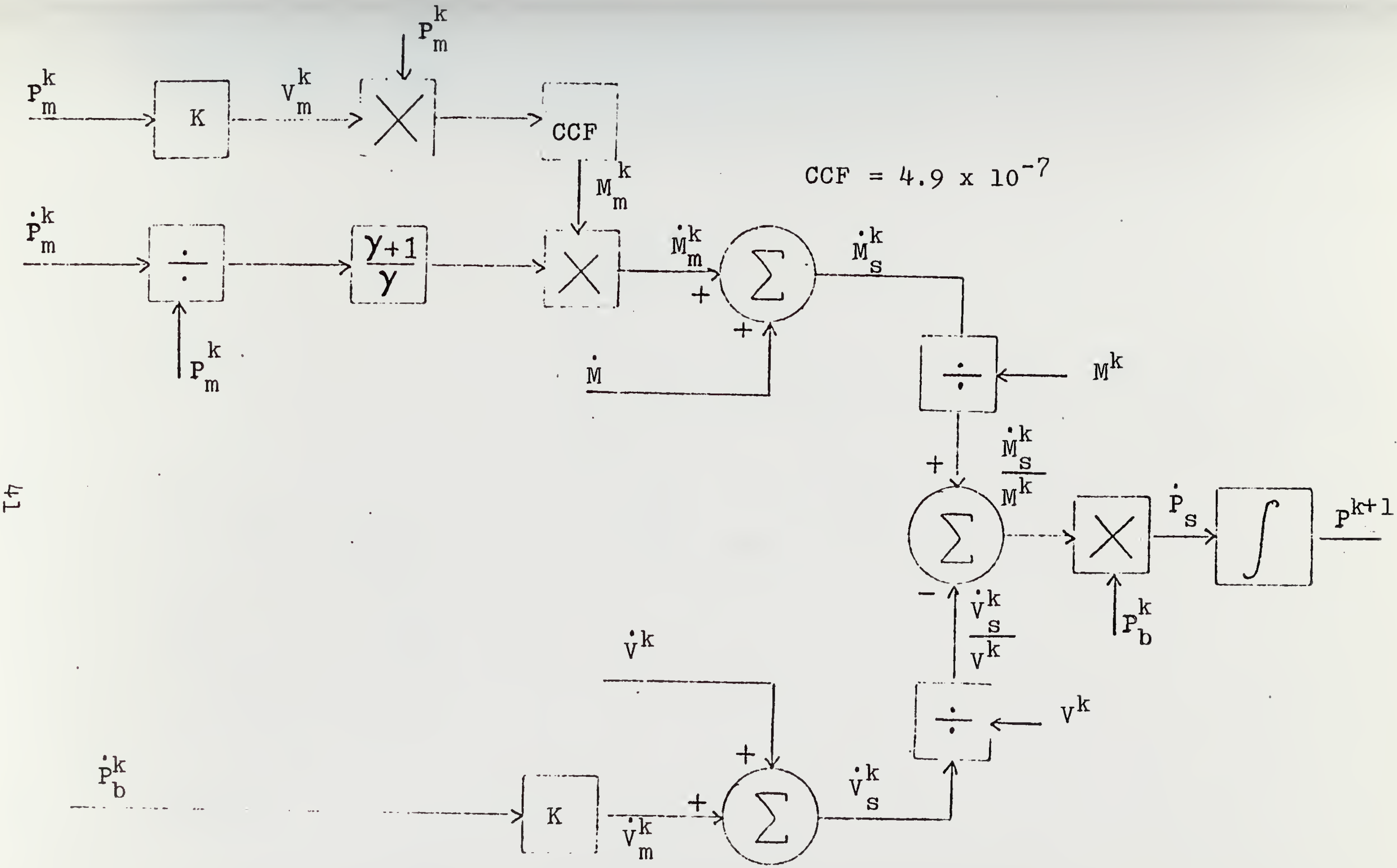


Figure 4. Computational Flow Diagram Model IV

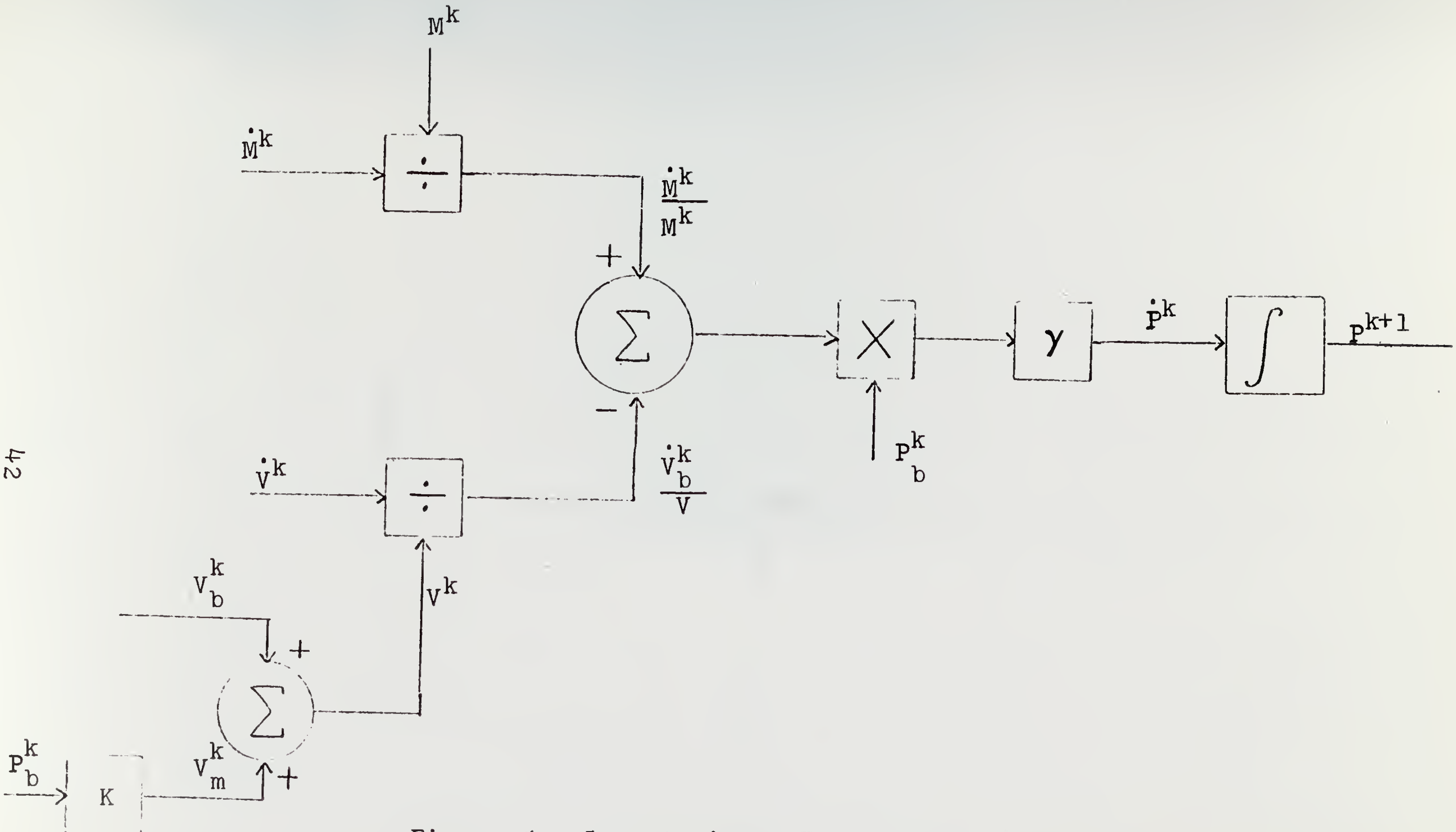


Figure 5. Computational Flow Diagram Model V

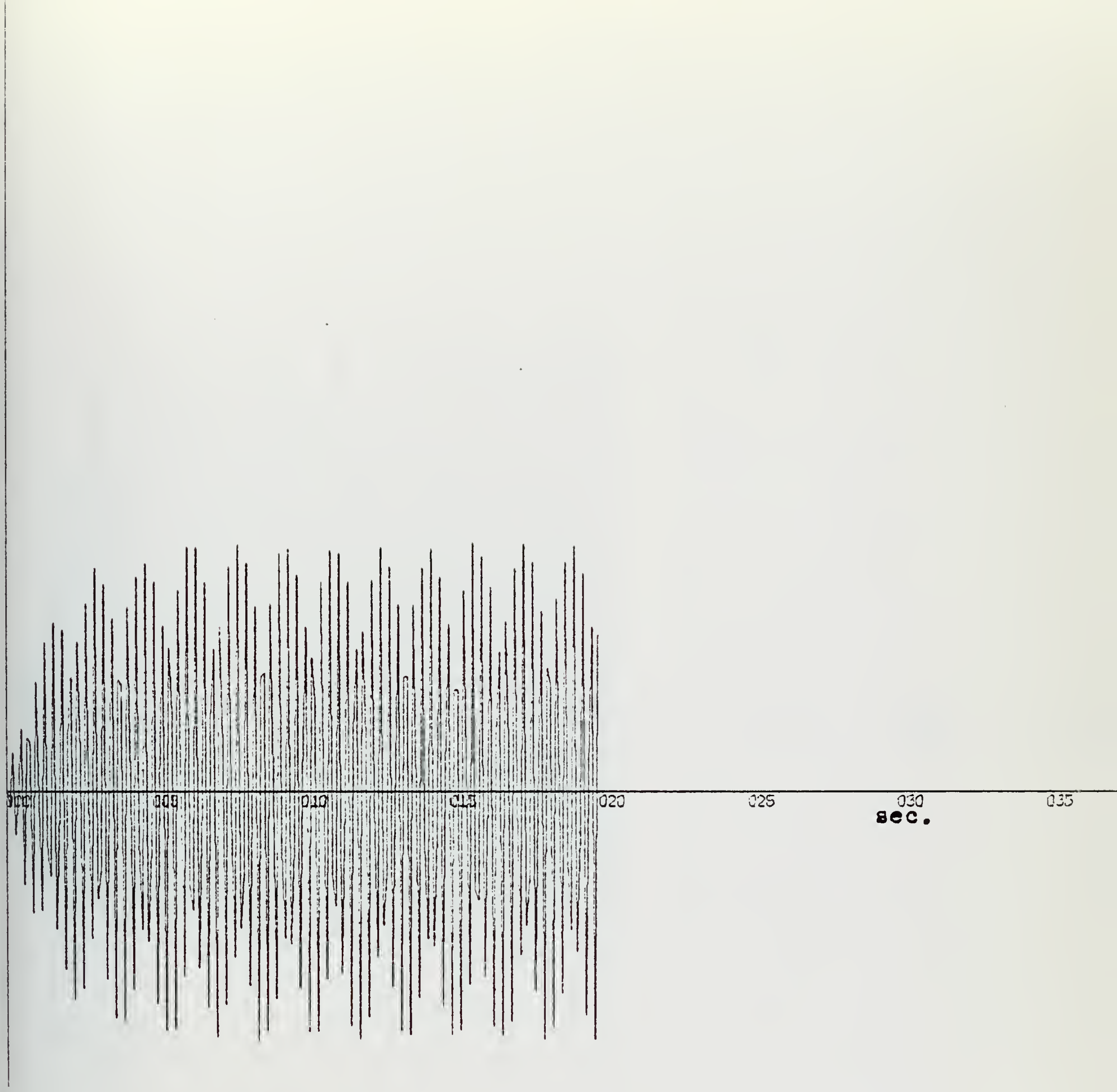


FIGURE 6

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=5.00E-02 UNITS INCH.
PROGRAM 2 MODEL 5 20KTS REG. SEA 1
PLOT IS C.G.ACCELERATION VERSUS TIME

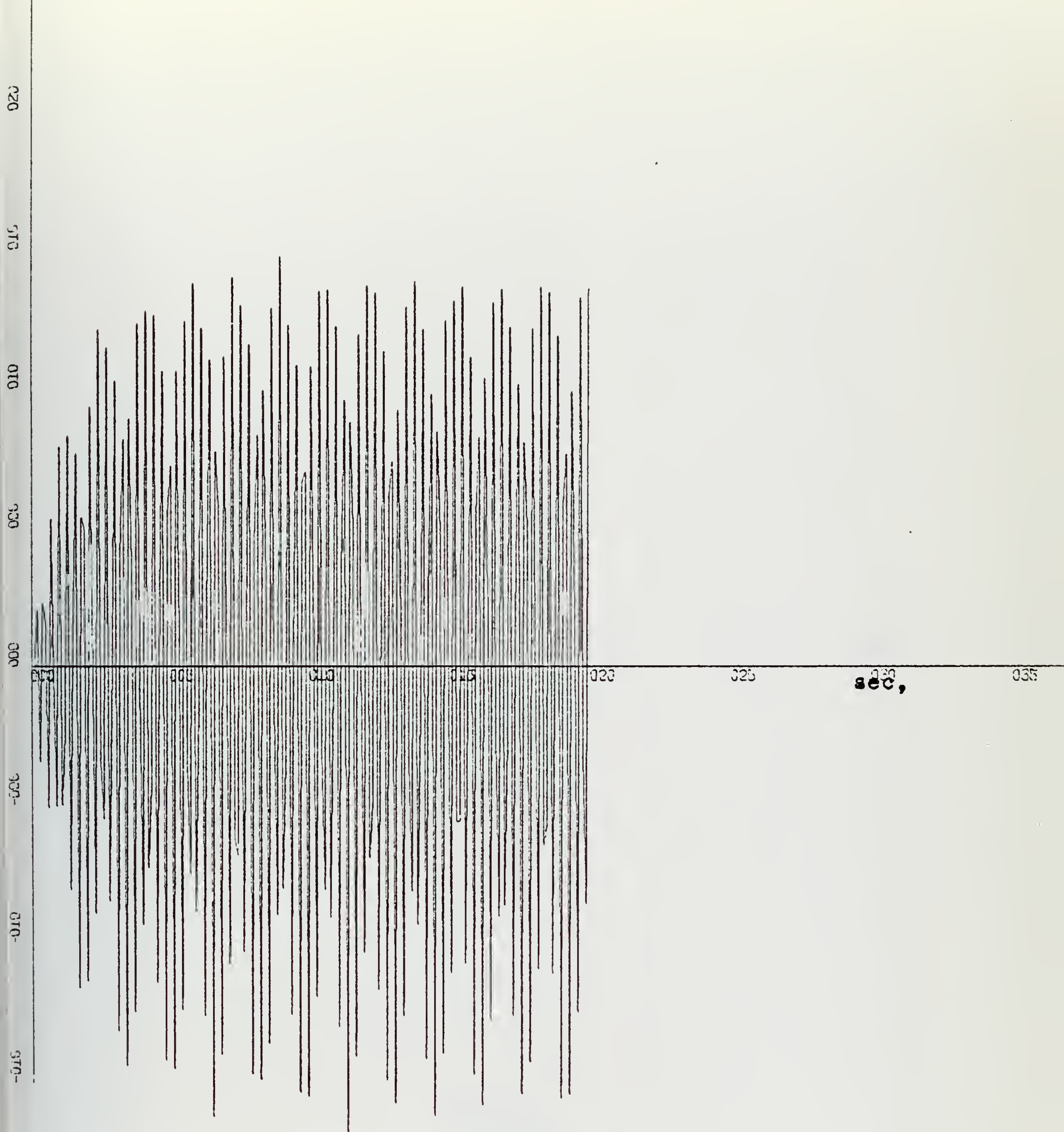


FIGURE 7

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=5.00E-02 UNITS INCH.
PRØGRAM 2 WITHOUT MEMBRANE REG. SEA 1
PLØT IS C.G.ACCELERATIØN VERSUS TIME

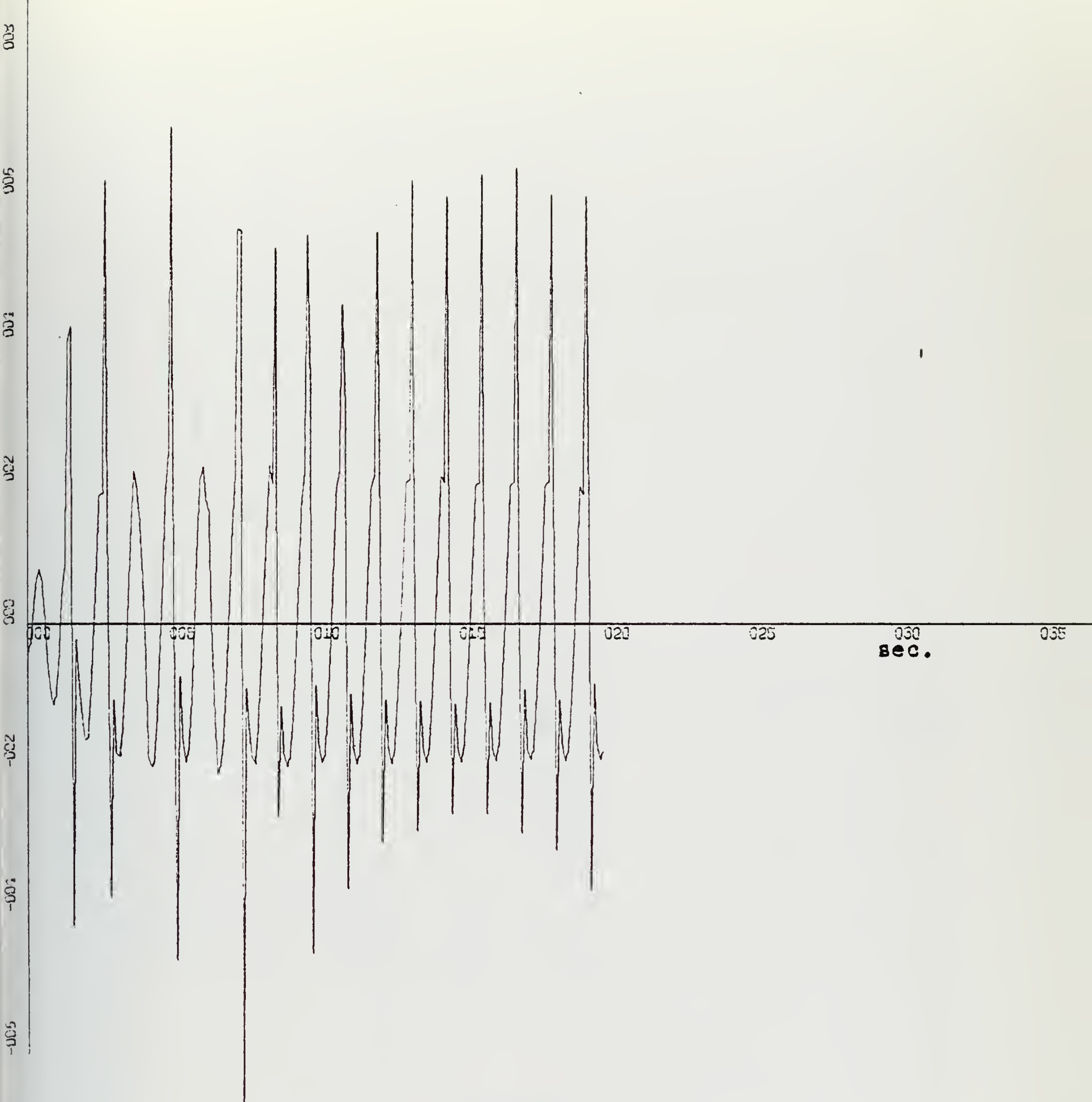


FIGURE 8

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
PROGRAM 2 MODEL 5 20KTS REG. SEA 2
PLOT IS C.G.ACCELERATION VERSUS TIME

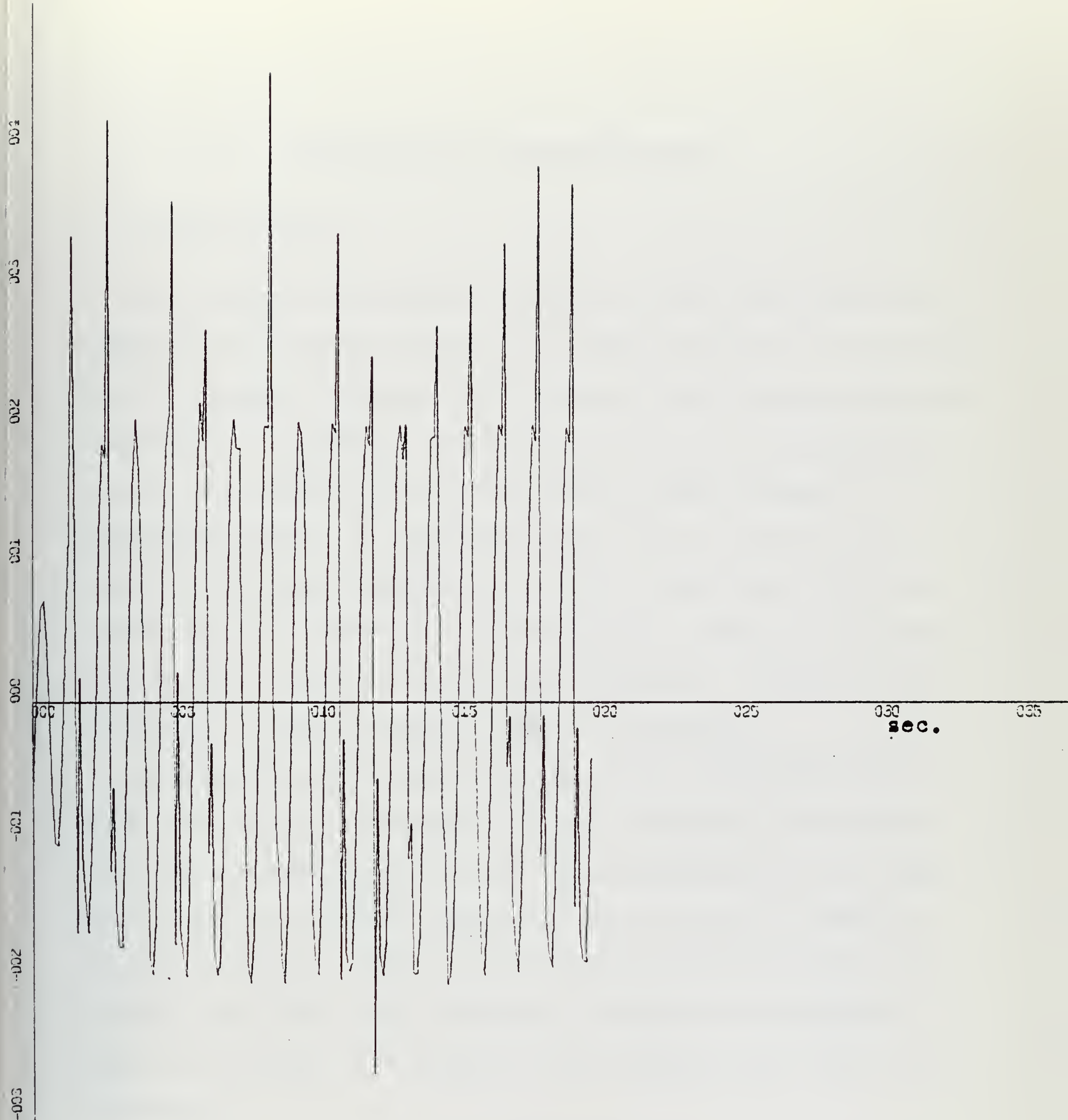


FIGURE 9

X-SCALE=5.00E+00 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.
PROGRAM 2 WITHOUT MEMBRANE REG. SEA 2
PLOT IS C.G.ACCELERATION VERSUS TIME

VI. CONCLUSIONS AND RECOMMENDATIONS

A. PROGRAM TIMING

The inclusion of pressure rate and volume rate equations improved the execution time of the L&M program without decreasing the program accuracy. The changes to the program were not difficult to implement. Further effort to improve execution time of the program should be directed toward changes to SUBROUTINE WAVES. In connection with this, a study of the number of required sidewall and bow and stern seal stations should also be conducted. By reducing the number of sidewall stations the execution time should decrease. A study of the losses in accuracy, however, would be necessary.

Another facet for investigation within SUBROUTINE WAVES would be a study to determine if the trignometric functions could be represented by the in-line programming of the expansion of sine and cosine functions, vice the use of computer library functions. Since some sine and cosine functions are nested in DO LOOPS small savings in time would accumulate. Again, the losses in accuracy to this change would have to be determined.

The elimination of SUBROUTINE DMINV did not produce any noticeable time savings but did save approximately 2 K bytes of core.

The expansion of the number of wave components did not demonstrate any time savings; however the optimum number of wave components required to simulate irregular sea conditions should be determined. A possible course of action would be to generate wave components, calculate the magnitude and frequency and compute the energy spectral density. This energy density spectrum could then be compared to the Pierson and Neumann or Moskowitz model [Ref. 11]. By determining the optimum number of wave components, a savings in CPU execution time could result.

B. ADDITIONAL MODELING

The fact that waves can hit the top of the plenum was discussed in Section V. Whether this effect produces significant forces and moments is unknown. Since the time that the wave is in contact with the plenum and the location (station numbers) is known and since the area of the plenum in contact with the waves could be approximated, (no greater than the difference between wetted stations) additional correction terms could be developed to determine whether significant forces and moments are generated by wave contact. The drag of the wetted plenum top could also be considered.

C. MEMBRANE MODELING

Of the five membrane models developed in this study, Model Five is the most usable. The accuracy of this model must be determined and the model must be validated. Whether

mass and mass flow rate terms could improve this model also needs to be determined. In this regard a detailed study of adiabatic-reversible unsteady flow conditions would be useful. This would mean the establishment of a suitable control volume and the solution of energy-work equations.

The membrane modeling in this study was for a continuous non-permeable membrane. Additional modeling for the case of a hole cut into the membrane should be attempted. The equation for a sharp-edge orifice could be used to determine air loss. The area (size) of the hole can be determined by considering as a first approximation the ratio of surface area of a hemisphere to volume of the hemisphere. As an alternative, the experimental results of the towing tank tests conducted at NSRDC, on the XR-1, using suitable scale factors, could be used to determine empirical correction factors to be applied to the Loads and Motion program.

The occurrences of algebraic loops and summation of feed forward terms as shown in the computational flow diagrams and the failure of the models in which they occur indicate that further modeling of the membrane is required. To prevent model failures, elimination of the effects of the computational loops appears to be necessary.

APPENDIX A

MEMBRANE SCALE FACTOR

The empirical relationship between pressure and volume for the membrane given in Ref. 9 is for the XR-1 test craft.

$$V_m = K\ P_m \tag{A1}$$

where

$$K = \frac{40\ in^3}{Psf}$$

It was therefore necessary to scale the constant K for the XR-3 test craft.

In the following development the subscript 1 refers to the XR-1 and subscript 3 refers to XR-3.

Since XR-1 and XR-3 are similar it was assumed that all dimensions scale by the ratio of plenum lengths

$$\frac{L_3}{L_1} = \lambda \tag{A2}$$

where

$L_3 = 20$ ft.

$L_1 = 5.4$ ft.

It was assumed that the ratio of mass to volume was constant

$$\frac{M_1}{V_1} = \frac{M_3}{V_3} = \rho \tag{A3}$$

The ratio of craft volume is

$$\frac{V_3}{V_1} = \lambda^3 \tag{A4}$$

The ratio of craft pressure is

$$\frac{P_3}{P_1} = \frac{M_{3g}/A_3}{M_{1g}/A_1} \tag{A5}$$

where g is the gravitational constant.

Substituting (A2) and (A3) into (A5)

$$\frac{P_3}{P_1} = \frac{V_3\ A_1}{V_1\ A_3} = \frac{\lambda^3}{\lambda^2} = \lambda \tag{A6}$$

Using (A4) and (A6) in (A1)

$$K_1 = \frac{V_1}{P_1} \quad \frac{V_3/\lambda^3}{P_3/\lambda} = \frac{K_3}{\lambda^2} \tag{A7}$$

$$K_3 = \lambda^2 K_1 \tag{A8}$$

Converting in.^{3} to ft.^{3} and using (A2)

$$K_3 = \left(\frac{20}{5.4}\right)^2 \quad \frac{40}{1728} = .3175 \text{ ft.}^3/\text{psf} \tag{A9}$$

APPENDIX B

<u>LISTING OF FORTRAN XR-3</u>

<u>L&M COMPUTER PROGRAM</u>

PROGRAM TWO MODEL FIVE

```
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /CONST/ PI,RAD,UO
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIP
     1(25),TIS(25)
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP
      COMMON /FROUDE/ FN,FNCRIT
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /ROLL/ PHIMAX,TROLL
      COMMON /RUDDR/ NPR,DELPUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,R
     1CLB,RTC,RUDANG,TIR(25)
      COMMON /VALOLD/ YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB),
     3 (VAL(12),VOL)
      DIMENSION DUMMY(20)
      TC = 1.0
      ON = 1
      PI = 4.*ATAN(1.)
      RAD = 180./PI
      WRITE (6,12)
    1 READ (44,13,END=2) DUMMY
      WRITE (6,14) DUMMY
      WRITE (5,13) DUMMY
      GO TO 1
    2 REWIND 5
    3 CALL INCON (TIME)
      IF (IMM.EQ.3) GO TO 11
      VAL(13) = VAL(24)
C
      DO 4 J=1,20
    4 YOLD(J) = VAL(J+1)
C
      GO TO 8
    5 CONTINUE
      TOLD = TIME
      PBBAR = PBBAR*(1.-DELT/TC)+DELT*(PB-PINF)/TC
```

```
      IF (NWAVE.LE.0) GO TO 6
      ZBAR = (1.-DELT/TC)*ZBAR+DELT*Z/TC
      PHIBAR = (1.-DELT/TC)*PHIBAR+DELT*PHI/TC
      THEBAR = (1.-DELT/TC)*THEBAR+DELT*THETA/TC
      CALL WAVES (TIME)
    6 CALL SIDEWL
      CALL PROP
      CALL RUDDER
      CALL AEROD
      CALL INTGRL (TIME)
      IF (TIME.GT.FTIME) GO TO 10
      IF (FN.GT.FNCRIT) GO TO 7
      PRINT 17
      GO TO 10
    7 DELOLD = TIME-TOLD
      PSI = PSI+DELOLD*R
      X = X+DELOLD*(U*COS(PSI)-V*SIN(PSI))
      Y = Y+DELOLD*(U*SIN(PSI)+V*COS(PSI))
      IF (ABS(TIME-TPRINT).LT.1.E-6) GO TO 8
      GO TO 5
    8 CONTINUE
      IF (ITRAJ.EQ.0) GO TO 9
      DPHI = PHI*RAD
      DPSI = PSI*RAD
      DTHETA = THETA*RAD
      DP = P*RAD
      DQ = Q*RAD
      DR = R*RAD
      VEL = 0.5925*U
      WRITE (6,15) TIME,VEL,V,W,DP,DQ,DR,Z,DPHI,DTHETA,X,Y,DPSI
      BETS = (-V/U)*RAD
      DELRS = RUDANG*RAD
      WRITE (6,16) BETS,DELRS,FXP
    9 CONTINUE
      IMMTAG = (IMM+1)/2
      IF (IMMTAG.EQ.1.AND.TIME.GE.BTIME-1.E-8) IMT=1
      TPRINT = TPRINT+DELPNT
      CN = 1
      GO TO 5
   10 CALL COLFIL
      IF (IMM.LT.1) GO TO 3
      IF (IMM.NE.1) GO TO 11
      END FILE IBMFIL
      GO TO 3
   11 CALL SAM
      GO TO 3
C
   12 FORMAT (1H1//35X,22H LISTING OF INPUT DECK//)
```

```
13 FORMAT (20A4)
14 FORMAT (5X,20A4)
15 FORMAT (//10X,13HTIME (SEC) = F6.2//10X,33HTRANSLATIONAL VELS (KTS
  1)/(FT/SEC)/10X,2HU=F6.2,5X,2HV=F6.2,5X,2HW=F6.3//10X,31HROTATIONAL
  2 VELOCITIES (DEG/SEC)/10X,2HP=F6.2,5X,2HQ=F6.2,5X,2HR=F6.2//10X,30
  3HDISPLACEMENTS (FT AND DEGREES)/10X,2HZ=F7.3,5X,4HPHI=F6.2,3X,6HTH
  4ETA=F6.2//10X,27HTRAJECTORY (FT AND DEGREES)/10X,2HX=F8.2,4X,2HY=F
  58.2,4X,4HPSI=F8.2)
16 FORMAT (1H0,9X,23HSIDESLIP ANGLE (DEG) = F8.2,10X,21HRUDDER ANGLE
  1(DEG) = F8.3,10X,15HTHRUST (LBS) = F12.1)
17 FORMAT (///25X,28HCRAFT SPEED BELOW HUMP SPEED)
   END

   SUBROUTINE AERODC
C
   INTEGER ON
   COMMON /FAERO/ FX,FY,FZ,FK,FM,FN
   COMMON /FAIR/ RHOA,XLAERO
   COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
   COMMON /PRTINT/ ON,IACCEL,IVFL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
  1RUD,IPROP,IAEROD,IRHS
   COMMON /VARBLE/ VAL(40)
   EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
  1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
  211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
C
   QA = RHOA*U*U
   QAL = QA*XLAERO
   BETA = -V/U
   BETASQ = BETA*BETA
   FX = -(0.90*BETASQ+0.13)*QA
   FY = (0.0*BETASQ+0.53*BETA)*QA
   FZ = -(2.06*BETASQ+0.39)*QA
   FK = -(0.5*BETASQ+0.0*BETA)*QAL
   FM = (0.29*BETASQ+0.12)*QAL
   FN = (0.0*BETASQ+0.076*BETA)*QAL
   IF (IAEROD.NE.ON) RETURN
   WRITE (6,1) FX,FY,FZ,FK,FM,FN
C
C
   RETURN
C
 1 FORMAT (/10X,23HAEROD FX,FY,FZ,FK,FM,FN/6E15.4)
   END

   BLOCK DATA
   COMMON /AIR/ Z1(3)
   COMMON /BMCO/ Z2(25)
```

```
COMMON /COLUMN/ Z3(2)                    BLDA  40
COMMON /CONST/ Z4(3)                     BLDA  50
COMMON /CNTRL/ Z5(10)                    BLDA  60
COMMON /ENGINE/ Z6(107)                  BLDA  70
COMMON /EQNCO/ Z7(22)                    BLDA  80
COMMON /FAERO/ Z8(6)                     BLDA  90
COMMON /FAIR/ Z9(2)                      BLDA 100
COMMON /FANMAP/ Z10(262)                 BLDA 110
COMMON /FORBS/ Z11(7)                    BLDA 120
COMMON /FORSS/ Z12(8)                    BLDA 130
COMMON /FPROP/ Z13(6)                    BLDA 140
COMMON /FROUDE/ Z14(2)                   BLDA 150
COMMON /FRUD/ Z15(6)                     BLDA 160
COMMON /GBOW/ Z16(1)                     BLDA 170
COMMON /GEOM/ Z17(138)                   BLDA 180
COMMON /GEOMBS/ Z18(62)                  BLDA 190
COMMON /GEOMSS/ Z19(62)                  BLDA 200
COMMON /GEOMSW/ Z20(11)                  BLDA 210
COMMON /KSWTCH/ Z21(1)                   BLDA 220
COMMON /LEAKER/ Z22(4)                   BLDA 230
COMMON /MASSES/ Z23(817)                 BLDA 240
COMMON /MATRIX/ Z24(36)                  BLDA 250
COMMON /MSIDW/ Z25(55)                   BLDA 260
COMMON /MWAVE/ Z26(12)                   BLDA 270
COMMON /OPTION/ Z27(4)                   BLDA 280
COMMON /PLENUM/ Z28(7)                   BLDA 290
COMMON /PRIME/ Z29(5)                    BLDA 300
COMMON /PRTINT/ Z30(12)                  BLDA 310
COMMON /PWAVE/ Z31(2)                    BLDA 320
COMMON /RISER/ Z32(1)                    BLDA 330
COMMON /ROLL/ Z33(2)                     BLDA 340
COMMON /RUDDP/ Z34(62)                   BLDA 350
COMMON /SIDE/ Z35(22)                    BLDA 360
COMMON /SOFTBS/ Z36(20)                  BLDA 370
COMMON /SOFTSS/ Z37(19)                  BLDA 380
COMMON /STABLE/ Z38(5)                   BLDA 390
COMMON /STSLR/ Z39(2)                    BLDA 400
COMMON /VALOLD/ Z40(20)                  BLDA 410
COMMON /VARBLE/ Z41(40)                  BLDA 420
COMMON /WAVE/ Z42(100)                   BLDA 430
COMMON /WAVEF/ Z43(80)                   BLDA 440
COMMON /SLOPE/ Z44(5)                    BLDA 450
COMMON /PROMOD/ Z45(7)                   BLDA 460
DATA Z1/3*0.0/                           BLDA 470
DATA Z2/25*0.0/                          BLDA 480
DATA Z3/2*0.0/                           BLDA 490
DATA Z4/3*0.0/                           BLDA 500
DATA Z5/10*0.0/                          BLDA 510
```

```
      DATA  Z6/107*0.0/                                               BLDA 520
      DATA  Z7/21*0.0/                                                BLDA 530
      DATA  Z8/6*0.0/                                                 BLDA 540
      DATA  Z9/2*0.0/                                                 BLDA 550
      DATA  Z10/262*0.0/                                              BLDA 560
      DATA  Z11/7*0.0/                                                BLDA 570
      DATA  Z12/8*0.0/                                                BLDA 580
      DATA  Z13/6*0.0/                                                BLDA 590
      DATA  Z14/2*0.0/                                                BLDA 600
      DATA  Z15/6*0.0/                                                BLDA 610
      DATA  Z16/0.0/                                                  BLDA 620
      DATA  Z17/138*0.0/                                              BLDA 630
      DATA  Z18/62*0.0/                                               BLDA 640
      DATA  Z19/62*0.0/                                               BLDA 650
      DATA  Z20/11*0.0/                                               BLDA 660
      DATA  Z21/0.0/                                                  BLDA 670
      DATA  Z22/4*0.0/                                                BLDA 680
      DATA  Z23/817*0.0/                                              BLDA 690
      DATA  Z24/36*0.0/                                               BLDA 700
      DATA  Z25/55*0.0/                                               BLDA 710
      DATA  Z26/12*0.0/                                               BLDA 720
      DATA  Z27/4*0.0/                                                BLDA 730
      DATA  Z28/7*0.0/                                                BLDA 740
      DATA  Z29/5*0.0/                                                BLDA 750
      DATA  Z30/12*0.0/                                               BLDA 760
      DATA  Z31/2*0.0/                                                BLDA 770
      DATA  Z32/0.0/                                                  BLDA 780
      DATA  Z33/2*0.0/                                                BLDA 790
      DATA  Z34/62*0.0/                                               BLDA 800
      DATA  Z35/22*0.0/                                               BLDA 810
      DATA  Z36/20*0.0/                                               BLDA 820
      DATA  Z37/19*0.0/                                               BLDA 830
      DATA  Z38/5*0.0/                                                BLDA 840
      DATA  Z39/2*0.0/                                                BLDA 850
      DATA  Z40/20*0.0/                                               BLDA 860
      DATA  Z41/40*0.0/                                               BLDA 870
      DATA  Z42/100*0.0/                                              BLDA 880
      DATA  Z43/80*0.0/                                               BLDA 890
      DATA  Z44/5*0.0/                                                BLDA 900
      DATA  Z45/7*0.0/                                                BLDA 910
      END                                                             BLDA 920
      SUBROUTINE BOWSL                                                BWSL  10
C                                                                     BWSL  20
      INTEGER CN                                                      BWSL  30
      COMMON /AIR/ PINF,RHOINF,GAM                                    BWSL  40
      COMMON /CONST/ PI,RAD,UO                                        BWSL  50
      COMMON /FORBS/ FX,FY,FZ,FK,FM,FN,QL                             BWSL  60
```

```
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)
     1,TSKIB(10)
      COMMON /LEAKER/ ALEAK,BLEAK,CFSS,CFBS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAV
     1GB(10),CENCAB
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      DIMENSION ELSKID(11), WETLEN(11), BWSL(6,24), GAP(11), ELSKI(11),
     1DPFT(11)
      DATA ENU,HINGHT/1.28E-5,1.875/
      DATA BWSL/0.0,3.8,6.9,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.0
     1,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12.
     24,15.4,18.3,0.0,5.5,9.6,13.3,16.1,19.6,0.0,5.8,9.9,13.8,17.1,20.6,
     30.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,11
     4.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,24
     5.1,28.3,0.0,8.2,15.3,21.7,26.3,31.3,0.0,9.6,17.5,24.2,29.7,34.6,0.
     60,11.9,20.0,26.7,32.3,38.0,0.0,14.0,22.5,30.0,35.8,41.0,0.0,17.5,2
     75.5,32.5,39.7,44.5,0.0,21.0,30.0,37.4,42.0,47.0,0.0,24.6,33.7,41.0
     8,45.0,48.7,0.0,29.4,38.5,45.0,48.7,48.7,0.0,33.0,45.0,48.7,48.7,48
     9.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,4
     $8.7,48.7,48.7,48.7,48.7/
      DATA CORLEN/3.75/
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
C
C
      DO 1 J=1,11
      GAP(J) = 0.0
      ELSKI(J) = 0.0
      WETLEN(J) = 0.0
      ELSKID(J) = 0.0
    1 CONTINUE
C
      ALBS = 0.0
      FX = 0.0
      FZ = 0.0
```

```
      FK = 0.0
      FM = ).0
      FN = 0.0
      DELPBG = PBS-PB
      IF (DELPBG.LT.0.0) DELPBG=0.0
      PBAR = PB-PINF
      DELP = PBAR
      IF (DELP.LT.0.0) DELP=0.0
      ARGO = ELMAXB/CORLEN
      ANGO = ARSIN(ARGO)
      X1 = XBS+ZBS*THETA-CORLEN*COS(ANGO)
      Z1 = -Z-ZBS+XBS*THETA-ELMAXB*COS(THETA)
      DPTHFT = (5.5/(1.+(U/25.))**2)*0.0833
      IF (CENCAB.GT.1.1875) CENCAB=1.1875
      N = NSTA(3)
C
      DO 3 K=1,N
      DPFT(K) = DPTHFT
      ELSKI(K) = (ETA(3,K)-DETABX(K)*(XX(3,K)-X1)-Z1)+YY(3,K)*PHI+XLXPWV
     1*WATSLP
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT
      IF ((HINGHT-ELSKI(K)+DPFT(K)).GE.ELMAXB) DPFT(K)=ELMAXB-HINGHT+ELS
     1KI(K)
      IF (DPFT(K).LT.0.0) DPFT(K)=0.0
      ELSKID(K) = (ELSKI(K)-DPFT(K))*12.0
      IF ((HINGHT-ELSKID(K)/12.0).GE.ELMAXB) ELSKID(K)=(HINGHT-ELMAXB)*1
     12.0
      DPIN = DPFT(K)*12.0
      MM = DPIN
      MM1 = MM+1
      MM2 = MM1+1
      DINC = DPIN-MM
      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXB)
      IF (GAP(K).LT.0.0) GAP(K)=0.0
      IF (ELSKID(K).GE.0.) GO TO 2
      WETLEN(K) = ELSKI(K)
      GO TO 3
    2 MM3 = ELSKID(K)
      MM4 = MM3+1
      MM5 = MM4+1
      DLINC = ELSKID(K)-MM3
      BWSL1 = BWSL(MM1,MM4)
      BWSL2 = BWSL(MM1,MM5)
      BWSL3 = BWSL(MM2,MM4)
      BWSL4 = BWSL(MM2,MM5)
      BWSLA1 = (BWSL2-BWSL1)*DLINC+BWSL1
      BWSLA2 = (BWSL4-BWSL3)*DLINC+BWSL3
      WETLEN(K) = ((BWSLA2-BWSLA1)*DINC+BWSLA1)*0.08333
```

```
    3 CONTINUE                                                          BWSL1030
C                                                                       BWSL1040
      N = NSTA(3)-1                                                     BWSL1050
C                                                                       BWSL1060
      DO 10 J=1,N                                                       BWSL1070
      WETLAV = (WETLEN(J+1)+WETLEN(J))*0.5                              BWSL1080
      IF (WETLAV.LE.0.001) GO TO 8                                      BWSL1090
      DPFTAV = (DPFT(J+1)+DPFT(J))*0.5                                  BWSL1100
      ELSKIA = (ELSKI(J+1)+ELSKI(J))*0.5                                BWSL1110
      ELSKDA = (ELSKID(J+1)+ELSKID(J))*0.04166                          BWSL1120
      SEALHT = HINGHT-ELSKDA                                            BWSL1130
      DIFF = 2.0*CENCAB-(SEALHT+0.5)                                    BWSL1140
      IF (DIFF.GT.0.5) DIFF=0.5                                         BWSL1150
      ARM1B(J) = X1+WETLAV*0.5                                          BWSL1160
      ARM2B(J) = ZS-ELSKIA+DPFTAV*0.5                                   BWSL1170
      IF (DIFF.GE.0.25) GO TO 4                                         BWSL1180
      DFBS(J) = -DELP*DELYBS*WETLAV                                     BWSL1190
      GO TO 7                                                           BWSL1200
    4 FORLEN = XBF-WETLAV                                               BWSL1210
      IF (FORLEN.EQ.0.0) GO TO 5                                        BWSL1220
      ARGW = (HINGHT-ELSKIA)/FORLEN                                     BWSL1230
      IF (ARGW.GT.1.0) ARGW=1.0                                         BWSL1240
      ANGW = ARSIN(ARGW)                                                BWSL1250
      FORCOS = COS(ANGW)                                                BWSL1260
      GO TO 6                                                           BWSL1270
    5 FORCOS = 0.0                                                      BWSL1280
    6 DFBS(J) = -DELP*DELYBS*WETLAV-DELP*FORLEN*DELYBS*FORCOS*((FORLEN*0BWSL1290
     1.5*FORCOS)/(FORLEN*FORCOS+WETLAV/2.0))*((DIFF-0.25)*4.0)          BWSL1300
    7 ARG = 0.5*RHO*U*U*WETLAV*DELYBS                                   BWSL1310
      RESKI = U*WETLAV/ENU                                              BWSL1320
      CDTSKI = 0.427/(ALOG10(RESKI)-0.407)**2.64                        BWSL1330
      TSKIB(J) = -ARG*CDTSKI                                            BWSL1340
      GO TO 9                                                           BWSL1350
    8 DFBS(J) = 0.0                                                     BWSL1360
      TSKIB(J) = 0.0                                                    BWSL1370
    9 CONTINUE                                                          BWSL1380
      FX = FX+TSKIB(J)                                                  BWSL1390
      FZ = FZ+DFBS(J)                                                   BWSL1400
      FK = FK+DFBS(J)*YAVGB(J)                                          BWSL1410
      FM = FM-DFBS(J)*ARM1B(J)+TSKIB(J)*ARM2B(J)                        BWSL1420
      FN = FN-TSKIB(J)*YAVGB(J)                                         BWSL1430
      ALBS = ALBS+(GAP(J)+GAP(J+1))*DELYBS*0.5                          BWSL1440
   10 CONTINUE                                                          BWSL1450
C                                                                       BWSL1460
      ALBS = ALBS+BLEAK                                                 BWSL1470
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)                                 BWSL1480
      QL = CFBS*ALBS*SQFAC*SIGN(1.,PBAR)                                BWSL1490
      IF (IBCWSL.NE.ON) RETURN                                          BWSL1500
```

```
      WRITE (6,11) GAP,WETLEN,FX,FY,FZ,FK,FM,FN
C
C
      RETURN
C
   11 FORMAT (//10X,8HBOW SEAL/26H GAP (FT.) (PORT TO STBD.)/11F10.5/28H
     1 WETLEN(FT.) (PORT TO STBD.)/11F10.5/10X,23HBOWSL FX,FY,FZ,FK,FM,F
     2N/6E15.4)
      END

      SUBROUTINE COLFIL
C
      COMMON /AXIS/ NXYS(26)
      COMMON /COLUMN/ IVERT,ILATRL
      COMMON /CURVE/ NCURV(10)
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /GRAF/ NGRAF,NDRW
      COMMON /HEADG/ TICRD(6)
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /STEP/ STEP2
      COMMON /SUM/ ISUM1(8),ISUM2(8)
      REAL *8TICRD
      REAL LABEL
      REAL LAB(4)/'','1','2','3'/
      REAL *8NAMES(52)/'TIME','','WAVEHEI','GHT','ZDISPLA','CEMENT','PIT
     1CHAN','GLE','PLENUMP','RESSURE','BOWACCE','LERATION','C.G.ACCE','L
     2ERATION','FANPOWE','R(IDEAL)','ROLLANG','LE','YAWANGL','E','LATACC
     3E','LERATION','SPEEDTH','RUWATER','TURNRAD','IUS','PLENUMV','OLUME
     4','XDISPLA','CEMENT','YDISPLA','CEMENT','AIRFLOW','IN','AIRFLOW','
     5CUT','NETFORC','EXDIR','WAVEFOR','CEXDIR','THRUSTS','TARBOARD','TH
     6RUSTP','ORTSIDE','PITCH','RATE','ROLL','RATE','YAW','RATE','RUDDER
     7A','NGLE'/
      REAL *8TITLE(12)
      REAL *8LINE2(2)/'PLOTIS','VERSUS'/
      REAL *8NAMEX(2),NAMEY(2),INAME(16)
      EQUIVALENCE (TITLE(1),TICRD(1)), (TITLE(2),TICRD(2)), (TITLE(3),TI
     1CRD(3)), (TITLE(4),TICRD(4)), (TITLE(5),TICRD(5)), (TITLE(6),TICRD
     2(6))
      DIMENSION PVQQ(26), XOUT(900), YOUT(900), AFILE(8)
      DIMENSION THSTS(1), THSTP(1)
      EQUIVALENCE (PVQQ(1),TIME), (PVQQ(2),ETA), (PVQQ(3),Z), (PVQQ(4),T
     1HETA), (PVQQ(5),PB), (PVQQ(6),BOWACC), (PVQQ(7),ACC), (PVQQ(8),FAN
     2PWR), (PVQQ(9),PHI), (PVQQ(10),BETAS), (PVQQ(11),ACCLAT), (PVQQ(12
     3),U), (PVQQ(13),TRADUS), (PVQQ(14),VOLP), (PVQQ(15),X), (PVQQ(16),
     4Y), (PVQQ(17),QIN), (PVQQ(18),QOUT), (PVQQ(19),GFXXX), (PVQQ(20),F
     5XPWAV), (PVQQ(21),THSTS(1)), (PVQQ(22),THSTP(1)), (PVQQ(23),QDEG),
     6 (PVQQ(24),PDEG), (PVQQ(25),RDEG), (PVQQ(26),DELRS)
C
```

```
      IF (JQQ.NE.2) GO TO 1
      WRITE (6,23) STEP2
    1 END FILE 1
      REWIND 1
      TITLE(7) = LINE2(1)
      TITLE(10) = LINE2(2)
      IF (NGRAF.EQ.0) GO TO 7
      J = 1
      NGF = NGRAF
      INDEX = NGRAF*2
C
      DO 6 I=1,INDEX,2
      INDX = NXYS(I)
      INDY = NXYS(I+1)
      IQ = 0
    2 READ (1,END = 8) TIME,ETA,Z,THETA,PB,BOWACC,ACC,FANPWR,PHI,BETAS,A
     1CCLAT,U,TRADUS,VOLP,X,Y,QIN,QOUT,GFXXX,FXPWAV,THSTS(1),THSTP(1),QD
     2FG,PDEG,RDEG,DELRS
      IF (IQ.GE.900) GO TO 3
      IQ = IQ+1
      XOUT(IQ) = PVQQ(INDX)
      YOUT(IQ) = PVQQ(INDY)
      GO TO 2
    3 REWIND 1
      INX = INDX*2
      INY = INDY*2
      NAMEX(1) = NAMES(INX-1)
      NAMEX(2) = NAMES(INX)
      NAMEY(1) = NAMES(INY-1)
      NAMEY(2) = NAMES(INY)
      IF (NDRW.EQ.1) GO TO 4
C
      CALL PLOTP (XOUT,YOUT,-IQ,0)
C
      WRITE (6,24) NAMEX,NAMEY
      GO TO 6
    4 TITLE(8) = NAMEY(1)
      TITLE(9) = NAMEY(2)
      TITLE(11) = NAMEX(1)
      TITLE(12) = NAMEX(2)
      NCUR = NCURV(J)
      IF (NCUR.NE.0) GO TO 5
      LABEL = LAB(1)
C
      CALL DRAW (IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)
C
      J = J+1
      GO TO 6
```

```
    5 WRITE (2) IQ,NCUR,NGF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(L),L=1
     1,IQ)
      NGF = NGF-1
    6 CONTINUE
C
      IF ((NGF.EQ.0).AND.(NCUR.EQ.3)) GO TO 10
    7 IF (IVERT.NE.1) GO TO 16
      WRITE (6,25)
      K = 0
C
      DO 8 I=1,8
      IF (ISUM1(I).NE.0) K=K+1
    8 CONTINUE
C
      NUM1 = K
      IF (K.EQ.0) GO TO 16
      N = K*2
      J = 1
C
      DO 9 I=1,NUM1
      IDEX = ISUM1(I)*2
      INAME(J) = NAMES(IDEX-1)
      INAME(J+1) = NAMES(IDEX)
      J = J+2
    9 CONTINUE
C
      WRITE (6,26) (INAME(I),I=1,N)
      GO TO 14
   10 END FILE 2
      REWIND 2
      NGF = NGRAF
      J = 1
   11 READ (2,END = 38) IQ,NCUR,NGRAF,LABEL,(TITLE(K),K=1,12),(XOUT(L),Y
     1OUT(L),L=1,IQ)
      IF ((NGF.EQ.NGRAF).AND.(NCUR.EQ.J)) GO TO 12
      GO TO 11
   12 LABEL = LAB(J+1)
C
      CALL DRAW (IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)
C
      REWIND 2
      J = J+1
      IF (J.EQ.4) GO TO 13
      GO TO 11
   13 NGF = NGF-1
      IF (NGF.EQ.0) GO TO 7
      J = 1
      GO TO 11
```

```
   14 READ (1,END = 13) (PVQQ(I),I=1,26)
C
      DO 15 I=1,NUM1
      J = ISUM1(I)
   15 AFILE(I) = PVQQ(J)
C
      WRITE (6,27) (AFILE(I),I=1,NUM1)
      GO TO 14
      REWIND 1
   16 IF (ILATRL.NE.1) GO TO 22
      WRITE (6,28)
      K = 0
C
      DO 17 I=1,8
      IF (ISUM2(I).NE.0) K=K+1
   17 CONTINUE
C
      NUM2 = K
      IF (K.EQ.0) GO TO 21
      N = K*2
      J = 1
C
      DO 18 I=1,NUM2
      IDEX = ISUM2(I)*2
      INAME(J) = NAMES(IDEX-1)
      INAME(J+1) = NAMES(IDEX)
      J = J+2
   18 CONTINUE
C
      WRITE (6,26) (INAME(I),I=1,N)
   19 READ (1,END = 16) (PVQQ(I),I=1,26)
C
      DO 20 I=1,NUM2
      J = ISUM2(I)
   20 AFILE(I) = PVQQ(J)
C
      WRITE (6,27) (AFILE(I),I=1,NUM2)
      GO TO 19
   21 REWIND 1
   22 RETURN
C
   23 FORMAT ('0',4X,'THIS RUN USED VARIABLE STEP SIZE',/,'0',4X,'THE MI
     1NIMUM STEPSIZE RECORDED DURING THE RUN WAS',2X,E30.5)
   24 FORMAT (' ',20X,2A8,' IS THE INDEPENDENT VARIABLE AND ',2A8,' THE
     1DEPENDENT VARIABLE')
   25 FORMAT ('0',50X,'***SUMMARY ONE***',/,'0')
   26 FORMAT ('0',16A8)
   27 FORMAT ('0',8(3X,F10.2,3X))
```

```
28 FORMAT ('0',50X,'***SUMMARY TWO***',/,'0')
   END

   SUBROUTINE FAN
C
   INTEGER ON
   COMMON /AIR/ PINF,RHOINF,GAM
   COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,EN
  1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2
  25),TMEB(25),DELB(25),NB,TMES(25),DELS(25),NS
   COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
   COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
  1RUD,IPROP,IAEROD,IRHS
   COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAV
  1GB(10)
   COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
  1GS(10)
   COMMON /VARBLE/ VAL(40)
   DIMENSION QB(1), QM(1), QS(1), PBOW(1), PM(1), PS(1), HP(8)
   EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
  1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
  2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
  3, (VAL(24),PB)
   EQUIVALENCE (VAL(18),FANPWR)
   EQUIVALENCE (QBFAN(1),QB(1)), (QMFAN(1),QM(1)), (QSFAN(1),QS(1)),
  1(PBFAN(1),PBOW(1)), (PMFAN(1),PM(1)), (PSFAN(1),PS(1))
   DATA HP/2.9,2.3,1.95,1.77,1.85,2.05,1.93,1.62/
C
   BRAT = 8000/BRPM
   EMRAT = 8000/EMRPM
   SRAT = 8000/SRPM
   TL = VAL(1)
   IF (NB.EQ.0.0) GO TO 1
   DPBS = FG1(TL,NB,TMEB,DELB,ILB)
   PBS = PB+DPBS
 1 IF (NS.EQ.0.0) GO TO 2
   DPSS = FG1(TL,NS,TMES,DELS,ILS)
   PSS = PB+DPSS
 2 CONTINUE
   PB1 = PBS-PINF
   PB2 = PB-PINF
   PB3 = PSS-PINF
   PBARB = PB1*BRAT*BRAT
   PBARM = PB2*EMRAT*EMRAT
   PBARS = PB3*SRAT*SRAT
   QBOW = ENBFAN*FG1(PBARB,NPTSB,PBOW,QB,IB)/BRAT
   QMAIN = ENMFAN*FG1(PBARM,NPTSM,PM,QM,IM)/EMRAT
   QSTN = ENSFAN*FG1(PBARS,NPTSS,PS,QS,IS)/SRAT
```

```
      QIN =  QBOW+QMAIN+QSTN
      MB1 =  (QBOW/ENBFAN+5.0)/5.0
      MB2 =  MB1+1
      MB3 =  MB2+1
      BINC  =  ((QBOW/ENBFAN+5.0)-MB1*5.0)/5.0
      BFANHP  =  ((HP(MB3)-HP(MB2))*BINC+HP(MB2))*FNBFAN*(1./BRAT)**3
      MS1 =  (QSTN/ENSFAN+5.0)/5.0
      MS2 =  MS1+1
      MS3 =  MS2+1
      STINC  =  ((QSTN/ENSFAN+5.0)-MS1*5.0)/5.0
      SFANHP  =  ((HP(MS3)-HP(MS2))*STINC+HP(MS2))*ENSFAN*(1./SRAT)**3
      MM1 =  (QMAIN/ENMFAN+5.0)/5.0
      MM2 =  MM1+1
      MM3 =  MM2+1
      PLINC  =  ((QMAIN/ENMFAN+5.0)-MM1*5.0)/5.0
      PFANHP  =  ((HP(MM3)-HP(MM2))*PLINC+HP(MM2))*ENMFAN*(1./EMRAT)**3
      RELPWR  =  PFANHP+BFANHP+SFANHP
      FANPWR  =  (QBOW*PB1+QMAIN*PB2+QSTN*PB3)/550.
      FANEFF  =  FANPWR/RELPWR
      IF (IRHS.NE.ON) RETURN
      WRITE (6,3) QBOW,QMAIN,QSTN,PBARB,PBARM,PBARS,RELPWR,FANPWR,FANEFF
C
C
      RETURN
C
    3 FORMAT (//4H FAN/32H Q - BOW,MAIN,STERN (CU FT /SEC)3F12.1/28H DEL
     1P - BOW,MAIN,STERN (PSF)3F11.2/60H ACTUAL FAN POWER REQUIRED(HP),
     2IDEAL FAN POWER, EFFICIENCY 3F12.4)
      END

      FUNCTION FG1 (X,N,XT,YT,IX)
C
      DIMENSION XT(1), YT(1)
C
      IF (IX.LT.1) IX = 1
      IF (IX.GT.N-1) IX = N-1
      I = SIGN(1.0,X-XT(IX))
    1 IF (IX.LT.1.OR.IX.GE.N) GO TO 3
      IF (XT(IX).GT.X.OR.X.GT.XT(IX+1)) GO TO 2
      C = (X-XT(IX))/(XT(IX+1)-XT(IX))
      GO TO 4
    2 IX = IX+I
      GO TO 1
    3 C = IX/N
      IX = IX-I
    4 FG1 = YT(IX)+C*(YT(IX+1)-YT(IX))
      RETURN
      END
```

```
      SUBROUTINE INCON (TIME)
C
      REAL *8TICRD
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /AXIS/ NXYS(26)
      COMMON /ATRIX/ AMASSI,AIYYI,DIXX,DIXZ,DIZZ
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /COLUMN/ IVERT,ILATRL
      COMMON /CONST/ PI,RAD,UO
      COMMON /CNTRL/ CONTW,CONTQ,CONTTH,QMULT,LOUVER,ACONTZ,ACONTW,ZEQUI
     1L,THEQL,ACBASE
      COMMON /CURVE/ NCURV(10)
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIP
     1(25),TIS(25)
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /FAIR/ RHOA,XLAERO
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,EN
     1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2
     25),TMEB(25),DELB(25),NB,TMES(25),DETS(25),NS
      COMMON /FROUDE/ FN,FNCRIT
      COMMON /GBOW/ XBOW
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMSW/ XAVG(10),DS
      COMMON /GRAF/ NGRAF,NDRW
      COMMON /HEADG/ TICRD(6)
      COMMON /PWAVE/ FNCON,PWVCON
      COMMON /LEAKER/ ALEAK,BLEAK,CFSS,CFBS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /MATRIX/ A(6,6)
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT,VMDOT,CMM
      COMMON /PLVCQQ/ NVI,NVD,NLI,NLD
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /ROLL/ PHIMAX,TROLL
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,R
     1CLB,RTC,RUDANG,TIR(25)
      COMMON /RISER/ AMPTC
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAV
     1GB(10),CENCAB
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
     1GS(10)
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      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSINCN 480
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC        INCN 490
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                    INCN 500
      COMMON /STABLE/ S(4),ISTAB                                        INCN 510
      COMMON /STSLR/ CPHI,CPHID                                         INCN 520
      COMMON /SUM/ ISUM1(8),ISUM2(8)                                    INCN 530
      COMMON /VALOLD/ YOLD(20)                                          INCN 540
      COMMON /VARBLE/ VAL(40)                                           INCN 550
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYINCN 560
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBINCN 570
     2BAR                                                               INCN 580
      COMMON /WAVEF/ WAVLEN(20),OMEGAE(20),WAVSLP(20),ENCPER(20)        INCN 590
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,ACINCN 600
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5INCN 610
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),AINCN 620
     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,INCN 630
     45,7),AS0(20,5,7),AS00(20,5,7),AS8(20,5,7),BB(36),XREF,RX          INCN 640
      DIMENSION ZZZ(14050)                                              INCN 650
      EQUIVALENCE (ZZZ,NAL)                                             INCN 660
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6INCN 670
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(INCN 680
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB),INCN 690
     3 (VAL(12),VOL)                                                    INCN 700
      DIMENSION TEMP(7), XMO(10)                                        INCN 710
      DIMENSION TITLC(20)                                               INCN 720
      DATA BEAM,BETAD,DELO,DELPI,DLRDO,DSO,ISYS,RMAXO,RONO,RRATO,RREVO,TINCN 730
     1HETO,THSSI,TPRINO,UO,VXO,VZO,XBSI,XCPO,XLTOT,XPO,XRO,XSSI,YPO,ZPO,INCN 740
     2ZRO,ZSSI/6*0.0,0,20*0.0/                                          INCN 750
C                                                                       INCN 760
C     INITIAL CONDITIONS WITH WATSLP                                    INCN 770
C                                                                       INCN 780
C                                                                       INCN 790
      DO 1 I=1,8                                                        INCN 800
      ISUM1(I) = 0                                                      INCN 810
    1 ISUM2(I) = 0                                                      INCN 820
C                                                                       INCN 830
      PINF = 2116.                                                      INCN 840
      RHOINF = .002378                                                  INCN 850
      GAM = 1.4                                                         INCN 860
      GO TO 3                                                           INCN 870
    2 READ (5,98) NGRAF,NDRW                                            INCN 880
      READ (5,99) NXYS                                                  INCN 890
      READ (5,100) TICRD                                                INCN 900
    3 READ (5,107) ISYSL,IOPT,(TEMP(I),I=1,7)                           INCN 910
      IF (ISYSL.EQ.ISYS.AND.ISYSL.EQ.13) GO TO 97                       INCN 920
      ISYS = ISYSL                                                      INCN 930
      IF ((ISYS.LE.0).OR.(ISYS.GT.22)) GO TO 97                         INCN 940
      GO TO (4,14,23,24,27,28,31,34,37,41,42,52,53,74,75,82,89,92,93,6,7INCN 950
```

```
     1,2), ISYS
C
C       PROGRAM CONTROL PARAMETERS
C
    4 CONTINUE
      GO TO (5,8,9,10,11,12), IOPT
    5 CONTINUE
      STIME = TEMP(1)
      FTIME = TEMP(2)
      DELO = TEMP(3)
      DELPNT = TEMP(4)
      TPRINO = TEMP(5)
      IF (TPRINO.LT.STIME+DELPNT) TPRINO=STIME+DELPNT
      IF (DELO.GT.DELPNT) DELO=DELPNT
      IF (DELO.EQ.0.0) GO TO 13
      GO TO 3
    6 READ (5,101) NCURV
      GO TO 3
    7 READ (5,102) ISUM1
      READ (5,102) ISUM2
      GO TO 3
    8 READ (5,108) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,IP
     1ROP,IAEROD,IRHS
      GO TO 3
    9 READ (5,111) NEQS,JQQ,(TOL(J),J=1,NEQS)
      GO TO 3
   10 READ (5,108) IVERT,ILATRL,NVD,NVI,NLD,NLI
      GO TO 3
   11 CONTINUE
      I3DOF = TEMP(1)
      ISRGE = TEMP(2)
      ITRIM = TEMP(3)
      IDIA = TEMP(4)
      GO TO 3
   12 CONTINUE
      PROMO1 = TEMP(1)
      PROMO2 = TEMP(2)
      PROMO3 = TEMP(3)
      PROMO4 = TEMP(4)
      PROMO5 = TEMP(5)
      PROMO6 = TEMP(6)
      PROMO7 = TEMP(7)
      GO TO 3
   13 WRITE (6,110)
      STOP
C
C       MASS DISTRIBUTION
C
```

```
   14 G = 32.17                                                          INCN1440
      RHO = 1.99                                                         INCN1450
      HRHO = RHO*.5                                                      INCN1460
      GO TO (15,17,22), IOPT                                             INCN1470
   15 IMM = 0                                                            INCN1480
      WEIGHT = TEMP(1)                                                   INCN1490
      AM = WEIGHT/G                                                      INCN1500
      XS = TEMP(2)                                                       INCN1510
      ZS = TEMP(3)                                                       INCN1520
      AIXX = TEMP(4)                                                     INCN1530
      AIYY = TEMP(5)                                                     INCN1540
      AIZZ = TEMP(6)                                                     INCN1550
      AIXZ = TEMP(7)                                                     INCN1560
C                                                                        INCN1570
C     INERTIA MATRIX OPERATIONS                                          INCN1580
C                                                                        INCN1590
   16 AMASSI = 1.0/AM                                                    INCN1600
      D = 1.0/(AIXX*AIZZ-AIXZ*AIXZ)                                      INCN1610
      DIXX = AIXX*D                                                      INCN1620
      DIXZ = AIXZ*D                                                      INCN1630
      DIZZ = AIZZ*D                                                      INCN1640
      AIYYI = 1.0/AIYY                                                   INCN1650
      GO TO 3                                                            INCN1660
C                                                                        INCN1670
C     READ WEIGHT DISTRIBUTION - ASSUME TRANSVERSE (PORT/STBD) SYMMETRY  INCN1680
C        X INPUT DIST. FWD. OF (SIDEWALL) TRANSOM                        INCN1690
C        Y INPUT DIST. TO STARBOARD                                      INCN1700
C        Z INPUT DIST. UP FROM KEEL-LINE                                 INCN1710
C                                                                        INCN1720
   17 I = 1                                                              INCN1730
   18 READ (5,109) AMI(I),XI(I),YI(I),ZI(I)                              INCN1740
      IF (AMI(I).LT.0.0) GO TO 19                                        INCN1750
      I = I+1                                                            INCN1760
      IF (I.GT.201) GO TO 97                                             INCN1770
      GO TO 18                                                           INCN1780
   19 NMASS = I-1                                                        INCN1790
      SUM = 0.0                                                          INCN1800
      SUX = 0.0                                                          INCN1810
      SUZ = 0.0                                                          INCN1820
C                                                                        INCN1830
      DO 20 I=1,NMASS                                                    INCN1840
      AMI(I) = AMI(I)/G                                                  INCN1850
      SUM = SUM+AMI(I)                                                   INCN1860
      SUX = SUX+AMI(I)*XI(I)                                             INCN1870
   20 SUZ = SUZ+AMI(I)*ZI(I)                                             INCN1880
C                                                                        INCN1890
      AM = SUM*2.0                                                       INCN1900
      WEIGHT = AM*G                                                      INCN1910
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```
      ZS =  SUZ/SUM                                                     INCN1920
      XS =  SUX/SUM                                                     INCN1930
      SUM =  0.0                                                        INCN1940
      SUX =  0.0                                                        INCN1950
      SUY =  0.0                                                        INCN1960
      SUZ =  0.0                                                        INCN1970
C                                                                       INCN1980
      DO 21  I=1,NMASS                                                  INCN1990
      XI(I)  =  XI(I)-XS                                                INCN2000
      ZI(I)  =  -ZI(I)+ZS                                               INCN2010
      AMK =  AMI(I)*2.0                                                 INCN2020
      SUX =  SUX+AMK*XI(I)*XI(I)                                        INCN2030
      SUY =  SUY+AMK*YI(I)*YI(I)                                        INCN2040
      SUZ =  SUZ+AMK*ZI(I)*ZI(I)                                        INCN2050
   21 SUM =  SUM+AMK*XI(I)*ZI(I)                                        INCN2060
C                                                                       INCN2070
      AIXX  =  SUY+SUZ                                                  INCN2080
      AIYY  =  SUX+SUZ                                                  INCN2090
      AIZZ  =  SUX+SUY                                                  INCN2100
      AIXZ  =  SUM                                                      INCN2110
      GO TO 16                                                          INCN2120
   22 GO TO  3                                                          INCN2130
C                                                                       INCN2140
C     XX AND YY TABLES                                                  INCN2150
C                                                                       INCN2160
   23 CONTINUE                                                          INCN2170
      NSTA(1)  =  TEMP(1)                                               INCN2180
      NSTA(2)  =  TEMP(2)                                               INCN2190
      NSTA(3)  =  TEMP(3)                                               INCN2200
      NSTA(4)  =  TEMP(4)                                               INCN2210
      XLTOT  =  TEMP(5)                                                 INCN2220
      GO TO  3                                                          INCN2230
C                                                                       INCN2240
C     SIDEWALL (INCLUDING APPENDAGES)                                   INCN2250
C                                                                       INCN2260
   24 CONTINUE                                                          INCN2270
      GO TO (25,26), IOPT                                               INCN2280
   25 YSW =  TEMP(1)                                                    INCN2290
      XLSW  =  TEMP(2)                                                  INCN2300
      CFSW  =  TEMP(3)                                                  INCN2310
      CDSW  =  TEMP(4)                                                  INCN2320
      AVBMSW  =  TEMP(5)                                                INCN2330
      READ (10) ZZZ                                                     INCN2340
      REWIND 10                                                         INCN2350
      GO TO  3                                                          INCN2360
C                                                                       INCN2370
C    BLOCK 4 OPTION 2 REMOVED.       NO APENDAGES                       INCN2380
C                                                                       INCN2390
```

```
   26 CONTINUE
      GO TO 3
C
C     STERNSEAL
C
   27 CONTINUE
      XSSI = TEMP(1)
      ZSSI = TEMP(2)
      ALEAK = TEMP(3)
      CFSS = TEMP(4)
      ELMAXS = TEMP(5)
      DPSS = TEMP(6)
      XLF = TEMP(7)
      ARGA = ELMAXS/XLF
      COSTH = ARGA
      THSSI = ARCOS(ARGA)
      SINTH = SIN(THSSI)
      GO TO 3
C
C     BOWSEAL
C
   28 GO TO (29,30), IOPT
   29 CONTINUE
      XBSI = TEMP(1)
      CFBS = TEMP(2)
      DPBS = TEMP(3)
      ZBSI = TEMP(4)
      ELMAXB = TEMP(5)
      XBF = TEMP(6)
      BLEAK = TEMP(7)
      GO TO 3
   30 CENCAB = TEMP(1)
      GO TO 3
C
C     PLENUM
C
   31 CONTINUE
      GO TO (32,33), IOPT
   32 CONTINUE
      XLBW = TEMP(1)
      XBBW = TEMP(2)
      XPWV = TEMP(3)
      WIDTH = TEMP(4)
      XL = TEMP(5)
      XCPO = TEMP(6)
      BUBHGT = TEMP(7)
      XLXPWV = XLBW-XPWV
      PWVHT = (XPWV*XPWV-XLXPWV*XLXPWV)*.5/XL
```

```
      XPWVXS = XPWV-XS                                                  INCN2880
      ABW = XBBW*XLBW                                                   INCN2890
      AB = WIDTH*XL                                                     INCN2900
      VCLNOM = (ABW+AB)*BUBHGT*.5                                       INCN2910
      GO TO 3                                                           INCN2920
   33 CONTINUE                                                          INCN2930
      FNCRIT = TEMP(1)                                                  INCN2940
      GO TO 3                                                           INCN2950
C                                                                       INCN2960
C     PROPULSICN                                                        INCN2970
C                                                                       INCN2980
   34 CONTINUE                                                          INCN2990
      GO TO (35,36), IOPT                                               INCN3000
   35 CONTINUE                                                          INCN3010
      XPO = TEMP(1)                                                     INCN3020
      YPO = TEMP(2)                                                     INCN3030
      ZPO = TEMP(3)                                                     INCN3040
      GO TO 3                                                           INCN3050
C                                                                       INCN3060
C BLOCK 8 OPTION 2 REMOVED. ENGINE OUT INPUT IN BLOCK 16                INCN3070
C                                                                       INCN3080
   36 CONTINUE                                                          INCN3090
      GO TO 3                                                           INCN3100
C                                                                       INCN3110
C     RUDDER                                                            INCN3120
C                                                                       INCN3130
   37 CCNTINUE                                                          INCN3140
      GO TO (38,39,40), IOPT                                            INCN3150
   38 XRO = TEMP(1)                                                     INCN3160
      YR = TEMP(2)                                                      INCN3170
      ZRO = TEMP(3)                                                     INCN3180
      RSPAN = TEMP(4)                                                   INCN3190
      RASPR = TEMP(5)                                                   INCN3200
      RAREA = TEMP(6)                                                   INCN3210
      RCLB = 2.*PI*RASPR/(RASPR+3.)                                     INCN3220
      RTC = TEMP(7)                                                     INCN3230
      GO TO 3                                                           INCN3240
C                                                                       INCN3250
C     910 NOT USED                                                      INCN3260
C                                                                       INCN3270
   39 CONTINUE                                                          INCN3280
      GO TO 3                                                           INCN3290
   40 CONTINUF                                                          INCN3300
      GO TO 3                                                           INCN3310
C                                                                       INCN3320
C     AERODYNAMICS                                                      INCN3330
C                                                                       INCN3340
   41 CONTINUE                                                          INCN3350
```

```
      XLAERO = TEMP(1)                                                  INCN3360
      BEAM = TEMP(2)                                                    INCN3370
      RHOA = .5*RHOINF*XLAERO*BEAM                                      INCN3380
      GO TO 3                                                           INCN3390
C                                                                       INCN3400
C     WAVES                                                             INCN3410
C                                                                       INCN3420
   42 CONTINUE                                                          INCN3430
      IWAVSW = ICPT                                                     INCN3440
      IF (IWAVSW.GT.4) GO TO 97                                         INCN3450
      NWAVE = TEMP(1)                                                   INCN3460
      IF (NWAVE.EQ.0) GO TO 3                                           INCN3470
      IF (NWAVE.GT.20) GO TO 97                                         INCN3480
      BETAD = TEMP(2)                                                   INCN3490
      BETA = BETAD/RAD                                                  INCN3500
      COSBET = COS(BETA)                                                INCN3510
      SINBET = SIN(BETA)                                                INCN3520
      TC = 1.0                                                          INCN3530
      GO TO (43,45,47,47), IWAVSW                                       INCN3540
C                                                                       INCN3550
   43 DO 44 I=1,NWAVE                                                   INCN3560
   44 READ (5,116) OMEGA(I),AW(I)                                       INCN3570
C                                                                       INCN3580
      GO TO 3                                                           INCN3590
C                                                                       INCN3600
   45 DO 46 I=1,NWAVE                                                   INCN3610
   46 READ (5,116) WAVLEN(I),AW(I)                                      INCN3620
C                                                                       INCN3630
      GO TO 3                                                           INCN3640
   47 SHTWV = TEMP(3)                                                   INCN3650
      G1G = 32.17                                                       INCN3660
      G2 = G1G*G1G                                                      INCN3670
      G4 = G2*G2                                                        INCN3680
      GO TO (3,3,48,49), IWAVSW                                         INCN3690
   48 CONTINUE                                                          INCN3700
      PERL = TEMP(4)                                                    INCN3710
      PERH = TEMP(5)                                                    INCN3720
      WWN = (2.0*3.141592)*(1.0/PERH)                                   INCN3730
      WWX = (2.0*3.141592)*(1.0/PERL)                                   INCN3740
      GO TO 50                                                          INCN3750
   49 CONTINUE                                                          INCN3760
      WWN = TEMP(4)                                                     INCN3770
      WWX = TEMP(5)                                                     INCN3780
   50 CONTINUE                                                          INCN3790
      UUU=SQRT(SHTWV*54.0)*1.6878                                       INCN3800
      UU4 = UUU*UUU*UUU*UUU                                             INCN3810
      CCC = (WWX/WWN)**(1./NWAVE)                                       INCN3820
      WWPO = WWN                                                        INCN3830
```

```
C
      DO 51  I=1,NWAVE
      WWPN  =  WWPO*CCC
      WW =  (WWPN+WWPO)*.5
      DDW =  WWPN-WWPO
      WWPO  =  WWPN
      WW4 =  WW*WW*WW*WW
      WW5 =  WW*WW4
      SS  =  0.0081*G2/(EXP(0.74*G4/(WW4*UU4))*WW5)
      OMEGA(I)  =  WW
      AW(I)  =  SQRT(2.*SS*DDW)
   51 CONTINUE
C
      GO TO 3
C
C     INITIAL CONDITIONS
C
   52 CONTINUE
      UO  =  TEMP(1)
      THETO  =  TEMP(2)
      DSO  =  TEMP(3)
      DELPI  =  TEMP(4)
      DPHI  =  TEMP(5)
      GO TO 3
   53 CONTINUE
C
C     INPUT COMPLETED. 1) PRINT ALL INPUT
C
      WRITE  (6,123)  TITLC
      WRITE  (6,124)  STIME,FTIME,DELO,TPRINO,DELPNT
      WRITE  (6,125)  IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,I
     1PROP,IAEROD,IRHS
      WRITE  (6,135)  I3DOF,ISRGE,ITRIM,IDIA
      WRITE  (6,142)  PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      WRITE  (6,126)  NEQS,(TOL(J),J=1,NEQS)
      WRITE  (6,113)  WEIGHT,XS,ZS,AIXX,AIYY,AIZZ,AIXZ
      WRITE  (6,112)  A,AIMAX
      WRITE  (6,133)  NSTA
      WRITE  (6,114)  YSW,XLSW,CFSW,CDSW,VANGLE,VSPAN,VCHORD,VXO,VY,VZO,AV
     1BMSW,VTC
      WRITE  (6,115)  NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB
      IF (IMM.GT.0)  WRITE  (6,121)  (XMO(J),J=1,IMNX)
      WRITE  (6,119)  IMM,IMNX,IMNY,IBMFIL,BTIME,IMT
      IF (IMM.GT.0)  WRITE  (6,122)  (YMI(J),J=1,IMNY)
      WRITE  (6,128)  XLBW,XBBW
      WRITE  (6,129)  XL,WIDTH,XCPO,VOLNOM,BUBHGT
      WRITE  (6,134)  DELPI
      WRITE  (6,127)  FNCRIT,XLTOT
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      WRITE (6,141) ENBFAN,BRPM,ENMFAN,EMRPM,ENSFAN,SRPM               INCN4320
      WRITE (6,131) XRO,YR,ZRO,RONO,RMAXO,RRATO,RREVO,DLRDO,RSPAN,RASPR,INCN4330
     1RAREA,RCLB,RTC                                                   INCN4340
      WRITE (6,130) XPO,YPO,ZPO                                         INCN4350
      WRITE (6,140) XLAERO,BEAM                                         INCN4360
      WRITE (6,139) XBSI,CFBS,DPBS,ELMAXB                               INCN4370
      WRITE (6,138) XSSI,ZSSI,ALEAK,CFSS,ELMAXS,DPSS,XLF                INCN4380
      WRITE (6,132) UO,THETO,DSO                                        INCN4390
C                                                                       INCN4400
C                 AND 2) INITIALIZE VARIABLES FOR CALCS.                INCN4410
C                                                                       INCN4420
C                                                                       INCN4430
      DO 54 I=1,40                                                      INCN4440
   54 VAL(I) = 0.0                                                      INCN4450
C                                                                       INCN4460
      U = UO*1.6889                                                     INCN4470
      XSS = -(XS-XSSI)                                                  INCN4480
      ZSS = ZS-ZSSI                                                     INCN4490
      THETA = THETO/RAD                                                 INCN4500
      PHI = DPHI/RAD                                                    INCN4510
      THEQL = THETA                                                     INCN4520
      DS = DSO*.0833                                                    INCN4530
      Z = -ZS+DS                                                        INCN4540
      ZEQUIL = Z                                                        INCN4550
      PHIMAX = 0.                                                       INCN4560
      TROLL = 0.                                                        INCN4570
      IRDS = 0                                                          INCN4580
      TL = 0.0                                                          INCN4590
C                                                                       INCN4600
C     WAVE PARAMETERS TABLE                                             INCN4610
C                                                                       INCN4620
      IF (NWAVE.EQ.0) GO TO 61                                          INCN4630
      AMPTC = 1.30287                                                   INCN4640
      GO TO (55,57), IWAVSW                                             INCN4650
C                                                                       INCN4660
   55 DO 56 I=1,NWAVE                                                   INCN4670
   56 WAVLEN(I) = 2.*PI*G/(OMEGA(I)*OMEGA(I))                           INCN4680
C                                                                       INCN4690
      GO TO 59                                                          INCN4700
C                                                                       INCN4710
   57 DO 58 I=1,NWAVE                                                   INCN4720
   58 OMEGA(I) = SQRT(2.*PI*G/WAVLEN(I))                                INCN4730
C                                                                       INCN4740
   59 CONTINUE                                                          INCN4750
C                                                                       INCN4760
C     CALCULATE INITIAL FREQUENCIES OF ENCOUNTER                        INCN4770
C                                                                       INCN4780
C                                                                       INCN4790
```

```
      DO 60  I=1,NWAVE
      WAVSLP(I)  = 360.0*AW(I)/WAVLEN(I)
      CMEGAE(I)  = 2.*PI*(SQRT(G*WAVLEN(I)/(2.*PI))-U*COSBET)/WAVLEN(I)
      ENCPER(I)  = 2.0*PI/OMEGAE(I)
   60 CONTINUE
C
      WRITE (6,117) NWAVE,BETAD,(OMEGA(I),OMEGAE(I),WAVLEN(I),AW(I),WAVS
     1LP(I),ENCPER(I),I=1,NWAVE)
      GO TO 62
   61 WRITE (6,118)
   62 CONTINUE
C
      DO 63  I=1,4
C
      DO 63  N=1,11
   63 ETA(I,N)  =  0.0
C
      DVOLW  =  0.0
      FXWAV  =  0.0
      FYWAV  =  0.0
      FZWAV  =  0.0
      FKWAV  =  0.0
      FMWAV  =  0.0
      FNWAV  =  0.0
      ZBAR  =  Z
      PHIBAR  =  PHI
      THEBAR  =  THETA
      TIME  =  STIME
      DELT  =  DELC
      TPRINT  =  TPRINO-DELPNT
      PWVCON  =  4.*WEIGHT/(RHO*G*XLBW)
      FNCON  =  SQRT(XLBW*G)
      VX  =  VXO-XS
      VZ  =  ZS-VZO
      XP  =  XPO-XS
      XR  =  XRO-XS
      YP  =  YPO
      ZP  =  ZS-ZPO
      ZR  =  ZS-ZRO
      IF (INM.EQ.0) GO TO 65
C
      DO 64  J=1,IMNX
   64 XMI(J)  =  XMO(J)-XS
C
   65 CONTINUE
      XCP  =  XCPO-XS
      ZCP  =  ZS-BUBHGT
      XBS  =  XBSI-XS
```

```
      N = NSTA(3)
      ZBS = ZS-ZBSI
C
      DO 66 J=1,N
      DELYBS = XBBW/(N-1)
      XX(3,J) = XBS-XSSI
      YY(3,J) = -0.5*XBBW+(J-1)*DELYBS
   66 CONTINUE
C
      N = N-1
C
      DO 67 J=1,N
      YAVGB(J) = (YY(3,J+1)+YY(3,J))*.5
   67 CONTINUE
C
      N = NSTA(4)
      DELYSS = XBBW/(N-1)
C
      DO 68 J=1,N
      XX(4,J) = -XS
      YY(4,J) = -.5*XBBW+(J-1)*DELYSS
   68 CONTINUE
C
      N = N-1
C
      DO 69 J=1,N
      YAVGS(J) = (YY(4,J+1)+YY(4,J))*.5
   69 CONTINUE
C
      XBOW = XLTOT-XS
      N = NSTA(1)
      DELX = XBSI/(N-1)
C
      DO 70 J=1,2
C
      DO 70 I=1,N
      XX(J,I) = (I-1)*DELX-XS
   70 YY(J,I) = YSW*(2*J-3)
C
      WRITE (6,103) ((XX(J,N),N=1,11),(YY(J,N),N=1,11),J=1,4)
      N = NSTA(1)-1
C
      DO 71 I=1,N
   71 XAVG(I) = DELX*(2*I-1)*.5-XS
C
C
      CALL WAVES (TIME)
C
```

```
C      INITIALIZE BUBBLE PRESSURE, ABSOLUTE (PSF)
C
       PB = PINF+DELPI
       PBBAR = DELPI
       PBAR = DELPI
       PSS = PB+DPSS
       PBS = PB+DPBS
       AB = ABW-(ABW-AB)*(ZS+Z/BUBHGT)
       CF = .37/((U/FNCON)**1.5655981)
       WATSLP = PBBAR*CF*PWVCON/WEIGHT
       IF (IDIA.EQ.1) GO TO 72
       VOL = VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW+.5*WATSLP*XL*AB
       GO TO 73
    72 VOL = VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW+PBAR*.3175+.5*WATSLP*XL*AB
    73 CONTINUE
       BMASS = (PB/PINF)**(1./GAM)*VOL*RHOINF
       WRITE (6,137)
       DVWDOT = 0.0
       RETURN
C
C      RUN TERMINATOR
C
    74 WRITE (6,106)
       STOP
C
C      BENDING MOMENT
C
    75 GO TO (76,77,79,81), IOPT
    76 IMM = TEMP(1)
       IF (IMM.GT.3) GO TO 97
       IMNX = TEMP(2)
       IF (IMNX.GT.10) GO TO 97
       IMNY = TEMP(3)
       IF (IMNY.GT.7) GO TO 97
       IBMFIL = TEMP(4)
       BTIME = TEMP(5)
       IF (IMM.EQ.3) IMT = TEMP(6)
       GO TO 3
C
    77 DO 78 J=1,7
    78 XMO(J) = TEMP(J)
C
       IF (IMNX.LE.7) GO TO 3
       READ 120, (XMO(J),J=8,IMNX)
       GO TO 3
C
    79 DO 80 J=1,IMNY
    80 YMI(J) = TEMP(J)
```

```
C                                                           INCN6240
      GO TO 3                                               INCN6250
   81 CONTINUE                                              INCN6260
      GO TO 3                                               INCN6270
   82 CONTINUE                                              INCN6280
      GO TO (83,85,87), IOPT                                INCN6290
   83 CONTINUE                                              INCN6300
C                                                           INCN6310
C   VALUES INPUT FOR STBD SCREW                             INCN6320
C                                                           INCN6330
      THST1 = TEMP(1)                                       INCN6340
      NPS = TEMP(2)                                         INCN6350
      STHS = TEMP(3)                                        INCN6360
      IF (NPS.EQ.0.0) GO TO 84                              INCN6370
      READ (5,104) (TIS(J),J=1,NPS)                         INCN6380
      READ (5,104) (THSTS(J),J=1,NPS)                       INCN6390
      GO TO 3                                               INCN6400
   84 THSTS(1) = THST1                                      INCN6410
   85 CONTINUE                                              INCN6420
C                                                           INCN6430
C   VALUES INPUT FOR PORT SCREW                             INCN6440
C                                                           INCN6450
      THST2 = TEMP(1)                                       INCN6460
      NPP = TEMP(2)                                         INCN6470
      STHP = TEMP(3)                                        INCN6480
      IF (NPP.EQ.0.0) GO TO 86                              INCN6490
      READ (5,104) (TIP(J),J=1,NPP)                         INCN6500
      READ (5,104) (THSTP(J),J=1,NPP)                       INCN6510
      GO TO 3                                               INCN6520
   86 THSTP(1) = THST2                                      INCN6530
   87 CONTINUE                                              INCN6540
C                                                           INCN6550
C   VALUES INPUT FOR RUDDER                                 INCN6560
C                                                           INCN6570
      DELR = TEMP(1)                                        INCN6580
      NPR = TEMP(2)                                         INCN6590
      IF (NPR.EQ.0.0) GO TO 88                              INCN6600
      READ (5,104) (TIR(J),J=1,NPR)                         INCN6610
      READ (5,104) (DELRUD(J),J=1,NPR)                      INCN6620
      GO TO 3                                               INCN6630
   88 DELRUD(1) = DELR                                      INCN6640
      GO TO 3                                               INCN6650
   89 GO TO (90,91), IOPT                                   INCN6660
   90 NB = TEMP(1)                                          INCN6670
      READ (5,104) (TMEB(I),I=1,NB)                         INCN6680
      READ (5,104) (DELB(I),I=1,NB)                         INCN6690
      GO TO 3                                               INCN6700
   91 NS = TEMP(1)                                          INCN6710
```

```
      READ (5,104) (TMES(I),I=1,NS)
      READ (5,104) (DETS(I),I=1,NS)
      GO TO 3
C
C     TITLE CARD (ALL 80 COLUMNS )
C
   92 READ (5,136) TITLC
      GO TO 3
C
C     FAN MAPS
C
   93 CONTINUE
      GO TO (94,95,96), IOPT
   94 CONTINUE
      ENBFAN = TEMP(1)
      BRPM = TEMP(2)
      NPTSB = TEMP(3)
      READIN = TEMP(4)
      IF (READIN.EQ.0.0) GO TO 3
      READ (5,104) (PBFAN(J),J=1,NPTSB)
      READ (5,104) (QBFAN(J),J=1,NPTSB)
      GO TO 3
   95 CONTINUE
      ENMFAN = TEMP(1)
      EMRPM = TEMP(2)
      NPTSM = TEMP(3)
      READIN = TEMP(4)
      IF (READIN.EQ.0.0) GO TO 3
      READ (5,104) (PMFAN(J),J=1,NPTSM)
      READ (5,104) (QMFAN(J),J=1,NPTSM)
      GO TO 3
   96 CONTINUE
      ENSFAN = TEMP(1)
      SRPM = TEMP(2)
      NPTSS = TEMP(3)
      READIN = TEMP(4)
      IF (READIN.EQ.0.0) GO TO 3
      READ (5,104) (PSFAN(J),J=1,NPTSS)
      READ (5,104) (QSFAN(J),J=1,NPTSS)
      GO TO 3
C
C     ERROR IN INPUT
C
   97 CONTINUE
      WRITE (6,105) ISYS
      STOP
C
C
```

```
 98 FORMAT (2I2)                                                                INCN7200
 99 FORMAT (26I2)                                                               INCN7210
100 FORMAT (6A8)                                                                INCN7220
101 FORMAT (10I1)                                                               INCN7230
102 FORMAT (8I2)                                                                INCN7240
103 FORMAT (//17H XX AND YY ARRAYS/14H PORT SIDEWALL/2(11F10.2/),15H SINCN7250
   1TBD. SIDEWALL/2(11F10.2/),9H BOW SEAL/2(11F10.2/),11H STERN SEAL/2INCN7260
   2(11F10.2/))                                                                 INCN7270
104 FORMAT (8F10.0)                                                             INCN7280
105 FORMAT (34H INPUT ERROR - - - STOP - -  ISYS=,I3)                           INCN7290
106 FORMAT (1H1,20(/),50X,19H COMPLETED ALL RUNS)                               INCN7300
107 FORMAT (I3,I2,7F10.0)                                                       INCN7310
108 FORMAT (16I5)                                                               INCN7320
109 FORMAT (5F10.0)                                                             INCN7330
110 FORMAT (///10X,65HERROR IN INPUT --- DELT AND/OR DELPNT EQUALS ZERINCN7340
   10 --- JOB ABORTED)                                                          INCN7350
111 FORMAT (2I2/(8F10.0))                                                       INCN7360
112 FORMAT (22H INERTIA MATRIX, AIMAX6E15.4/(22X,6F15.4))                       INCN7370
113 FORMAT (30H WEIGHT, C.G., INERTIA MOMENTS7F12.3)                            INCN7380
114 FORMAT (15H SIDEWALL INPUT12(F8.3,1X))                                      INCN7390
115 FORMAT (26H SIDEWALL TABLE PARAMETERS4(I4,F7.3,F7.3))                       INCN7400
116 FORMAT (2F10.0)                                                             INCN7410
117 FORMAT (/12HONO OF WAVESI2,10H BETA(DEG)F5.0/15H OMEGA(RAD/SEC),5XINCN7420
   1,16H OMEGAE(RAD/SEC)5X,16H WAVE LENGTH(FT)5X,14H AMPLITUDE(FT)5X,1INCN7430
   26HMAX  SLOPE (DEG)5X,13HPERIOD,E(SEC)/(F8.4,12X,F8.4,4F20.3))               INCN7440
118 FORMAT (/11HOCALM WATER)                                                    INCN7450
119 FORMAT (32HOMOMENT CALC. CONTROL PARAMETERS4I5,F8.3,I5)                     INCN7460
120 FORMAT (5X,7F10.0)                                                          INCN7470
121 FORMAT (22H MOMENT CALCS. AT X OF11F10.3)                                   INCN7480
122 FORMAT (22H MOMENT CALCS. AT Y OF11F10.3)                                   INCN7490
123 FORMAT (33H1SES MOTIONS AND LOADS PROGRAM - 20A4,/)                         INCN7500
124 FORMAT (23H START AND FINISH TIMES2F10.2/22H INITIAL TIME INTERVALINCN7510
   1F12.4/18H START PRINTING ATF8.2,17H IN INCREMENTS OFF8.2)                   INCN7520
125 FORMAT (24H INTERMEDIATE PRINT TAGS16I5)                                    INCN7530
126 FORMAT (39H NO. OF STATE EQUATIONS, AND TOLERANCESI5/(10X,10E12.2)INCN7540
   1)                                                                           INCN7550
127 FORMAT (23HOCRITICAL FROUDE NUMBERF15.4,5X,19H TOTAL CRAFT LENGTHFINCN7560
   115.4)                                                                       INCN7570
128 FORMAT (34HOPLENUM, LENGTH AND WIDTH AT WATER2F12.4)                        INCN7580
129 FORMAT (34H PLENUM, LENGTH AND WIDTH AT HULL 2F12.4/35H PLENUM, CEINCN7590
   1NTER OF PRESSURE AT HULLF12.4/23H PLENUM, NOMINAL VOLUMEF12.1,10X,INCN7600
   26HHEIGHTF12.4)                                                              INCN7610
130 FORMAT (/33H PROPULSION, X, Y, Z COORDINATES 3F12.4/)                       INCN7620
131 FORMAT (/28HORUDDER, X, Y, Z COORDINATES3F12.4/41H RUDDER, ON, MAXINCN7630
   1, RATE, REVERSE, INITIAL 5F12.4/33H RUDDER,SPAN,ASPECT,AREA,CLB,T/INCN7640
   2C 5F12.4)                                                                   INCN7650
132 FORMAT (/39HOINITIAL CONDITIONS, VELOCITY (KNOTS) =F7.2,5X,13HPITCINCN7660
   1H (DEG) =F8.3,5X,12HDRAFT (IN) =F8.2)                                       INCN7670
```

```
133 FORMAT (49H NUMBER OF STATIONS, SIDEWALLS (P+S), SEALS (B+S),4I5)
134 FORMAT (38H PLENUM, INITIAL PRESSURE, GAGE (PSF) F8.2)
135 FORMAT (79H PROGRAM OPTION SWITCH SETTINGS (LATERAL PLANE,CONSTANT
   1 SPEED,TRIM,MEMBRANE)    7I5)
136 FORMAT (20A4)
137 FORMAT (1H1)
138 FORMAT (16H STERNSEAL INPUT7F12.4)
139 FORMAT (16H BOWSEAL INPUT  7F12.4)
140 FORMAT (19HOAERODYNAMICS INPUT7F12.4)
141 FORMAT (33HOFANS, NO. + RPM, BOW,MAIN,STERN 3(F10.0,F10.1))
142 FORMAT (32H PROGRAM MODIFICATICN SETTINGS  7(F12.4,1X))
    END

    SUBROUTINE INTGRL (TIME)
    INTEGER ON
    COMMON /AIR/ PINF,RHOINF,GAM
    COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
    COMMON /EQNCO/ NEQS,TOL(20),JQQ
    COMMON /KSWTCH/ ITHRST
    COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
   1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
    COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA
    COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT,VMDOT,PMDOT
    COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
    COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
    COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
   1RUD,IPROP,IAEROD,IRHS
    COMMON /STABLE/ S(4),ISTAB
    COMMON /STEP/ STEP2
    COMMON /VALOLD/ YOLD(20)
    COMMON /VARBLE/ VAL(40)
    EQUIVALENCE (VAL(1),X), (VAL(2),Y(1))
    DIMENSION Y(20), ERROR(20)
    REAL K1(20),K2(20),K3(20),K4(20),K5(20)
    DATA IPASS/0/
    STEP2 = 1.0
    PB = VAL(24)
    BMASS = Y(10)
    IF ((TIME+DELT).LE.TPRINT) GO TO 1
    DEL = DELT
    DELT = TPRINT-TIME
    IPASS = 1
  1 X = TIME
C
    DO 2 J=1,NEQS
    Y(J) = YOLD(J)
  2 CONTINUE
C
```

```
      ITHRST = 1
      CALL RHS (K1)
      ITHRST = 2
      IMT = 0
      IF (IACCEL.NE.ON) GO TO 3
      ACCLAT = (K1(2)+Y(1)*Y(6))/G
      WRITE (6,20) ACCLAT,DELT
    3 ON = 2
    4 H = DELT/3.
      X = TIME+H
C
      DO 5 J=1,NEQS
    5 Y(J) = YOLD(J)+H*K1(J)
C
      CALL RHS (K2)
C
      DO 6 J=1,NEQS
    6 Y(J) = YOLD(J)+.5*H*(K1(J)+K2(J))
C
      CALL RHS (K3)
      X = TIME+.5*DELT
C
      DO 7 J=1,NEQS
    7 Y(J) = YOLD(J)+.375*H*(K1(J)+3.*K3(J))
C
      CALL RHS (K4)
      X = TIME+DELT
C
      DO 8 J=1,NEQS
    8 Y(J) = YOLD(J)+.5*H*(3.*K1(J)-9.*K3(J)+12.*K4(J))
C
      CALL RHS (K5)
      IF (JCC.EQ.1) GO TO 9
C
      DO 9 J=1,NEQS
      ERROR(J) = (K1(J)-4.5*K3(J)+4.*K4(J)-.5*K5(J))*H/5.0
      IF (ABS(ERROR(J)).GT.TOL(J)) GO TO 15
    9 CONTINUE
C
C
      DO 10 J=1,NEQS
      Y(J) = YOLD(J)+.5*H*(K1(J)+4.*K4(J)+K5(J))
   10 YOLD(J) = Y(J)
C
      TIME = TIME+DELT
      IF (IPASS.EQ.1) GO TO 14
      IF (JCC.EQ.1) GO TO 12
C
```

```
      DO 11  J=1,NEQS
      IF (ABS(ERROR(J)).GT.TOL(J)/16.) GO TO 13
   11 CONTINUE
C
      DELT = 2.*DELT
      IF (DELT.GT.DELPNT) DELT=DELPNT
   12 RETURN
   13 STEP2 = DELT
      GO TO 12
   14 DELT = DEL
      IPASS = 0
      GO TO 12
   15 DELT = DELT/2.
      IF (DELT.LT.1.E-6) GO TO 18
      IF (JQQ.EQ.2) GO TO 17
      WRITE (6,22) TIME,DELT,J,ERROR(J),TOL(J)
   16 IPASS = 0
      GO TO 4
   17 STEP1 = DELT*2.0
      IF (STEP1.LT.STEP2) STEP2=STEP1
      GO TO 16
   18 WRITE (6,21)
      WRITE (6,19) TIME,DELT,(K1(J),J=1,NEQS),VAL
      STOP
C
   19 FORMAT (/10X,23HINTGRL TIME,DELT,K1,VAL/2E15.4/2(6E15.4/),5(8E15.4
     1/))
   20 FORMAT (1H0,9X,33HTOTAL LATERAL ACCELERATION (G) = F12.4,12X,5HDT
     1= E15.4)
   21 FORMAT (1H1,10X,44HDELTA TIME LESS THAN 1.0E-6  -  -  JOB STOPS)
   22 FORMAT (/10X,5HINT-J2E30.5,I5,2E20.5)
      END

      SUBROUTINE PROP
C
      INTEGER ON
      COMMON /CONST/ PI,RAD,UO
      COMMON /FPROP/ FX,FY,FZ,FK,FM,FN
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIP
     1(25),TIS(25)
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,R
     1CLB,RTC,RUDANG,TIR(25)
      COMMON /VARBLE/ VAL(40)
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
```

```
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      DIMENSION THS(1), THP(1), TS(1), TP(1), RUD(1), TR(1)
      EQUIVALENCE (THSTS(1),THS(1)), (THSTP(1),THP(1)), (TIS(1),TS(1)),
     1(TIP(1),TP(1)), (TIR(1),TR(1)), (DELRUD(1),RUD(1))
C
      FX = 0.0
      FY = 0.0
      FZ = 0.0
      FK = 0.0
      FM = 0.0
      FN = 0.0
      TL = TIME
      IF (NPR.EQ.0.0) GO TO 1
      RUDANG = FG1(TL,NPR,TR,RUD,IR)
      RUDANG = RUDANG/RAD
C
C     CALCULATE THRUSTS AND MOMENTS INDIVIDUALLY
C
      GO TO 2
    1 RUDANG = DELRUD(1)
      RUDANG = RUDANG/RAD
    2 CD = COS(RUDANG)
      SD = SIN(RUDANG)
      IF (NPS.EQ.0.0) GO TO 3
      THSS = FG1(TL,NPS,TS,THS,IS)
      GO TO 4
    3 THSS = THSTS(1)
    4 IF (NPP.EQ.0.0) GO TO 5
      THSP = FG1(TL,NPP,TP,THP,IP)
      GO TO 6
    5 THSP = THSTP(1)
    6 STHSTS = STHS*THSS
      STHSTP = STHP*THSP
      FXS = THSS*CD-STHSTS*SD
      FXP = THSP*CD+STHSTP*SD
      FYS = -STHSTS*CD-THSS*SD
      FYP = STHSTP*CD+SD*THSP
      FZS = -THSS*THETA*CD+STHSTS*SD*PHI
      FZP = -THSP*THETA*CD-STHSTP*SD*PHI
      FX = FXP+FXS
      FY = FYP+FYS
      FZ = FZP+FZS
      FKP = -FZP*YP-FYP*ZP
      FKS = FZS*YP-FYS*ZP
      FK = FKS+FKP
      FMS = FZS*(-XP)+FXS*ZP
      FMP = FZP*(-XP)+FXP*ZP
```

```
      FM = FMS+FMP
      FNS = -FXS*YP-FYS*(-XP)
      FNP = FXP*YP-FYP*(-XP)
      FN = FNS+FNP
      IF (IPROP.NE.ON) RETURN
      WRITE (6,7) FX,FY,FZ,FK,FM,FN
      RETURN
C
    7 FORMAT (/10X,22HPPROP FX,FY,FZ,FK,FM,FN/6F15.4)
      END

      SUBROUTINE RUDDER
C
      INTEGER ON
      COMMON /CONST/ PI,RAD,UO
      COMMON /FRUD/ FX,FY,FZ,FK,FM,FN
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /PRTINT/ ON,IACCFL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,R
     1CLB,RTC,RUDANG,TIR(25)
      COMMON /VARBLE/ VAL(40)
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      EQUIVALENCE (DELRUD(1),RUD(1)), (TIR(1),TR(1))
      DIMENSION RUD(1), TR(1)
      EQUIVALENCE (VAL(18),FANPWR)
      DATA ENU/1.28E-5/
C
C     CALCULATE PROGRAMMED RUDDER DEFLECTION
C
      TL = TIME
      IF (NPR.EQ.0.0) GO TO 1
      GO TO 2
    1 RUDANG = DELRUD(1)
      RUDANG = RUDANG/RAD
      GO TO 3
    2 RUDANG = FG1(TL,NPR,TR,RUD,IR)
      RUDANG = RUDANG/RAD
C
C     SIDE FORCE ON RUDDER
C
    3 DSR = Z+ZS-XR*THETA
      ENDFAC = (1.+DSR/(DSR+RSPAN))
```

```
      VH =  V+XR*R-ZR*P
      QQ =  HRHO*U*U*RAREA
      EFFANG =  RUDANG-ENDFAC*VH/U
      FY =  2.*QQ*ENDFAC*RCLB*EFFANG
C
C     DRAG FORCE ON RUDDER
C
      REY =  U*(RAREA/RSPAN)/ENU
      CFR =  .427/(ALOG10(REY)-.407)**2.64
      PI8 =  PI/8.
      CD =  2.*CFR+PI8*RTC*RTC*(1.+G*RSPAN/(U*U))+RCLB*EFFANG*EFFANG
      FX =  -2.*CD*RAREA*HRHO*U*U
      FZ =  0.
      FK =  -ZR*FY
      FM =  FX*ZR
      FN =  XR*FY
      IF (IRUD.NE.ON) RETURN
      WRITE (6,4) FX,FY,FZ,FK,FM,FN
C
C
      RETURN
C
    4 FORMAT (/10X,24HRUDDER FX,FY,FZ,FK,FM,FN/6E15.4)
      END

      SUBROUTINE RHS (VALUF)
      INTEGER CN
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /ATRIX/ AMASSI,AIYYI,DIXX,DIXZ,DIZZ
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /COLUMN/ IVERT,ILATRL
      COMMON /CONST/ PI,RAD,UO
      COMMON /CNTRL/ CONTW,CONTQ,CONTTH,QMULT,LOUVER,ACONTZ,ACONTW,ZEQUI
     1L,THEQL,ACBASE
      COMMON /ENGINE/ NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,TIP
     1(25),TIS(25)
      COMMON /FANMAP/ QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,EN
     1SFAN,BRPM,MRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(25
     2),TMEB(25),DELB(25),NB,TMES(25),DETS(25),NS
      COMMON /FAERO/ FXAED,FYAED,FZAED,FKAED,FMAED,FNAED
      COMMON /FORBS/ FXBS,FYBS,FZBS,FKBS,FMBS,FNBS,QLBS
      COMMON /FORSS/ FXSS,FYSS,FZSS,FKSS,FMSS,FNSS,QLSS,FMS
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP
      COMMON /FROUDE/ FN,FNCRIT
      COMMON /FRUD/ FXRUD,FYRUD,FZRUD,FKRUD,FMRUD,FNRUD
      COMMON /GBOW/ XBOW
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
```

```
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)RHS
     1,TSKIE(10)                                                        RHS
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)RHS
     1,ARM2S(10)                                                        RHS
      COMMON /KSWTCH/ ITHRST                                            RHS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMRHS
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                         PHS
      CCMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),FNRHS
     1H(2),VFY(2),VFZ(2),FXV                                            RHS
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)          RHS
      COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA                            RHS
      COMMCN /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT,VMDOT,CMM             RHS
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                     RHS
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRHS
     1RUD,IPROP,IAEROD,IRHS                                             RHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  RHS
      COMMON /PWAVE/ FNCON,PWVCON                                       PHS
      COMMON /RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,RRHS
     1CLB,RTC,RUDANG,TIR(25)                                            RHS
      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSRHS
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DELX,VTC         RHS
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                    RHS
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVRHS
     1GB(10),CENCAB                                                     RHS
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAVRHS
     1GS(10)                                                            RHS
      COMMON /VALOLD/ YOLD(20)                                          RHS
      COMMON /VARBLE/ VAL(40)                                           RHS
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYRHS
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBRHS
     2BAR                                                               RHS
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VARHS
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VARHS
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)RHS
     3, (VAL(24),PB)                                                    RHS
      EQUIVALENCE (VAL(18),FANPWR)                                      RHS
      DIMENSION ACCEL(3), ANGACL(3)                                     RHS
      DIMENSION GF(6), VALUE(20)                                        RHS
      DATA CCF/4.9E-07/                                                 RHS
C                                                                       RHS
C                                                                       RHS
      DO 1 J=1,20                                                       RHS
    1 VALUE(J) = 0.0                                                    RHS
C                                                                       PHS
C                                                                       RHS
C     CALCULATION OF BUBBLE WAVE MAKING DRAG                            RHS
C                                                                       RHS
      AB = ABW-(ABW-(XL*WIDTH))*(ZS+Z)/BUBHGT                           PHS
```

```
      FN = U/FNCON
      CF = .37/(FN**1.5655981)
      FXPWAV = -PWVCON*PBBAR*CF
      WATSLP = -FXPWAV/WEIGHT
      VOL = VAL(12)
      PB = VAL(13)
      PBAR = VAL(13)-PINF
      PBS = PB+DPBS
      PSS = PB+DPSS
      ABPB = PBAR*AB
C     CALCULATION OF BUBBLE WAVE MAKING DRAG
C
      FLOW = SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)
      CLSW = CFSW*ALSW*FLOW
C
      CALL BOWSL
      CALL STNSL
C
      SUMX = FXBS+FXSS+FXSW+FXRUD+FXP+FXWAV+FXAED+FXPWAV
      IF (ITHRST.NE.ITRIM) GO TO 2
      THSTS(1) = THSTS(1)-SUMX*.5
      THSTP(1) = THSTP(1)-SUMX*.5
      THST = THSTS(1)+THSTP(1)
      SUMX = 0.0
    2 CONTINUE
      SUMY = FYBS+FYSS+FYSW+FYRUD+FYP+FYWAV+FYAED
      SUMZ = WEIGHT-ABPB+FZBS+FZSS+FZSW+FZRUD+FZP+FZWAV+FZAED
      SUMK = FKBS+FKSS+FKSW+FKRUD+FKP+FKWAV+FKAED+ABPB*PHI*(-Z)
C
C     CALCULATION OF EFFECTIVE CENTER OF PRESSURE
C
      UU = U*0.5921-30.0
      XCPU = XCP+0.001975*UU*UU-0.974
      XCPC = SHXYAX(XCPU,ZCP,THETA,PI)
      FMBUB = ABPB*XCPC
      SUMM = FMBS+FMSS+FMSW+FMRUD+FMP+FMWAV+FMAED+FMBUB+FXPWAV*ZS
      FWAVZ = FXPWAV*ZS
      SUMN = FNBS+FNSS+FNSW+FNRUD+FNP+FNWAV+FNAED
      IF (I3DOF.NE.1) GO TO 3
      SUMZ = 0.0
      SUMM = 0.0
    3 CONTINUE
      VALUE(1) = SUMX*AMASSI
      VALUE(2) = SUMY*AMASSI-R*U
      VALUE(3) = SUMZ*AMASSI
      VALUE(4) = SUMK*DIZZ+SUMN*DIXZ
      VALUE(5) = SUMM*AIYYI
      VALUE(6) = SUMN*DIXX+SUMK*DIXZ
```

```
      VALUE(7) = P
      VALUE(8) = Q
      VALUE(9) = W
      IF (I3DOF.EQ.1) GO TO 6
C
C     BUBBLE PRESSURE EQUATION
C
      QOUT = QLBS+QLSS+QLSW
C
      CALL FAN
      VALUE(10) = RHOINF*(QIN-QOUT)
      VALUE(11) = -(((XL*WIDTH)+ABW)*.5)*W-DVWDOT
      VALUE(12) = VAL(13)*GAM*((VALUE(10)/VAL(11))-(VALUE(11)/VAL(12)))
      IF (IDIA.EQ.1) GO TO 4
      GO TO 5
    4 CONTINUE
C
C   MEMBRANE STUDY
C
      VAL(12)=VAL(12)+0.3175*VAL(13)
      VALUE(12)=VAL(13)*GAM*((VALUE(10)/VAL(11))-(VALUE(11)/VAL(12)))
    5 CONTINUE
      GO TO 7
    6 CONTINUE
      VALUE(10) = 0.0
    7 CONTINUE
C
C     WRITE DATA FILE FOR MOMENT AND SHEAR CALCS., IF REQUIRED
C
      IF (IMT.NE.1) GO TO 8
      NBS = NSTA(3)-1
      NSS = NSTA(4)-1
      NSSL = NSS/2+1
      WRITE (IBMFIL) (VAL(I),I=1,24),ZBAR,PHIBAR,THEBAR,FXW,FYW,FZW,FKW,
     1FMW,FNW,(VALUE(I),I=1,10),DF,DSWAV,FXH,FYH,FZH,FMH,FNH,VFY,VFZ,FXV
     2,FXRUD,FYRUD,FXP,FYP,FZP,FZSS,FKSS,FMSS,FXBS,FZBS,FXAED,FYAED,FZAE
     3D,FMAED,FNAED,FXPWAV,FXSS,FKBS,FMBS,FNBS,FNSS,(TSKIS(I),DFSS(I),I=
     4NSSL,NSS),(TSKIB(I),DFBS(I),ARM1B(I),ARM2B(I),I=1,NBS)
    8 CONTINUE
C
C     CONSTANT LONGITUDINAL VELOCITY ( U )
C
      IF (ISRGE.EQ.1) VALUE(1)=0.0
      IF (ON.NE.1) RETURN
C
      DO 9 I=1,3
      ACCEL(I) = VALUE(I)/G
      ANGACL(I) = VALUE(I+3)*RAD
```

```
    9 CONTINUE
C
      BOWACC = ACCEL(3)-XBOW*VALUE(5)/G
      STNACC = ACCEL(3)+XS*VALUE(5)/G
      IF (IVERT.NE.ON) GO TO 10
      ZD = Z+ZS
      VOLP = VOL
      THETAR = THETA*RAD
      QDEG = Q*RAD
   10 IF (ILATRL.NE.ON) GO TO 13
      DEPSI = PSI*RAD
      PDEG = P*RAD
      RDEG = R*RAD
      BETAS = -V/U*RAD
      ACCLAT = (VALUE(2)+U*R)/G
      DPHI = PHI*RAD
      DRFT = 12.0*ZD
      VEL = 0.5925*U
      DELRS = RUDANG*RAD
      IF (R.EQ.0.0) GO TO 11
      TRADUS = U/R
      GO TO 12
   11 TRADUS = 1.E8
   12 WRITE (1) TIME,VAL(16),DRFT,THETAR,PBAR,BOWACC,ACCEL(3),FANPWR,DPH
     1I,DEPSI,ACCLAT,VEL,TRADUS,VOLP,X,Y,QIN,QOUT,GF(1),FXPWAV,THSTS(1),
     2THSTP(1),QDEG,PDEG,RDEG,DELRS
   13 IF (IRHS.NE.ON) RETURN
      WRITE (6,14) FMBS,FMSS,FMSW,FMRUD,FMP,FMWAV,FMAED,FMBUB,FWAVZ
      WRITE (6,15) FXPWAV
      WRITE (6,16) PBAR,FANPWR,QIN,QLBS,QLSW,QLSS
      WRITE (6,17) AB,VOL
      WRITE (6,18) VALUE,VAL
      WRITE (6,19) GF,ACCEL,ANGACL
      WRITE (6,20) BOWACC,STNACC
C
C
      RETURN
C
   14 FORMAT ('0',6X,5HFMBS=,E16.6,2X,5HFMSS=,F16.6,2X,5HFMSW=,
     1 E16.6,/,'0',6X,6HFMRUD=,E16.6,2X,4HFMP=,E16.6,2X,6HFMWAV=,E16.6,
     2 /,'0',6X,6HFMAED=,E16.6,2X,6HFMBUB=,E16.6,2X,6HFWAVZ=,E16.6)
   15 FORMAT ('0',6X,7HFXPWAV=,E16.6)
   16 FORMAT (//10X,3HPHS20HGAGEPRESS.(PSF)=F7.2,5X,21HFAN POWER REQD (H
     1P) =F8.2,5X,27HFAN FLOW RATE (CU FT/SEC) =F9.2,//31H LEAKAGE FLOW
     2RATES (CU FT/SEC)//11H BOW SEAL =F9.2,11H SIDEWALL =F9.2,13H STERN
     3 SEAL =F9.2)
   17 FORMAT (/13H PLENUM AREA=F9.2,10X,14HPLENUM VOLUME=F10.2)
   18 FORMAT (//12H VALUE ARRAY2(/10E13.4)/10H VAL ARRAY4(/10E13.4))
```

```
19 FORMAT (/10X,24HTOTAL FORCES AND MOMENTS6E12.4/10X,24HACCELERATIONRHS 2170
  1S G,DEG/SEC26E12.4)                                                 RHS 2180
20 FORMAT (/10X,16HBOW ACCEL. (G) =F12.4,21H   STERN ACCEL. (G) =E12.RHS 2190
  14)                                                                  RHS 2200
   END                                                                 RHS 2210

   SUBROUTINE SAM                                                      SAM   10
C                                                                      SAM   20
   WRITE (6,1)                                                         SAM   30
   RETURN                                                              SAM   40
C                                                                      SAM   50
 1 FORMAT (1H1,'YOU HAVE CALLED A DUMMY SAM SUBROUTINE.'/              SAM   60
  110X,'CHANGE TO BHISES TO USE THE SAM SUBROUTINE.')                  SAM   70
   END                                                                 SAM   80

   SUBROUTINE SIDEWL                                                   SDWL  10
C                                                                      SDWL  20
   INTEGER ON                                                          SDWL  30
   COMMON /AIR/ PINF,RHOINF,GAM                                        SDWL  40
   COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY  SDWL  50
   CCMMON /CONST/ PI,RAD,UO                                            SDWL  60
   COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,SDWL  70
  110),XCP,ZCP                                                         SDWL  80
   COMMON /GEOMSW/ XAVG(10),DS                                         SDWL  90
   COMMON /KSWTCH/ ITHRST                                              SDWL 100
   COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMSDWL 110
  1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                           SDWL 120
   COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),FNSDWL 130
  1H(2),VFY(2),VFZ(2),FXV                                              SDWL 140
   COMMON /PLENUM/ XLBW,XBBW,ABW,BUBHGT,DVWDOT                         SDWL 150
   COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                       SDWL 160
   COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,ISDWL 170
  1RUD,IPROP,IAEROD,IRHS                                               SDWL 180
   COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7   SDWL 190
   COMMON /SIDE/ FX,FY,FZ,FK,FM,FN,ALSW,YSW,XLSW,CFSW,CDSW,VAREA,VCHOSDWL 200
  1RD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVBMSW,DFLX,VTC                       SDWL 210
   COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                      SDWL 220
   CCMMON /VARBLE/ VAL(40)                                             SDWL 230
   COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYSDWL 240
  1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBSDWL 250
  2BAR                                                                 SDWL 260
   COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,ACSDWL 270
  11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5SDWL 280
  2,7),AC7(20,5,7),ACO(20,5,7),ACOO(20,5,7),AC8(20,5,7),AS1(20,5,7),ASDWL 290
  3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,SDWL 300
  45,7),ASO(20,5,7),ASOO(20,5,7),AS8(20,5,7),BB(36),XREF,RX           SDWL 310
   EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6SDWL 320
  1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(SDWL 330
```

```
 211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
      DIMENSICN GAP(2,11), DSW(2,11)
      DIMENSION FZHOLD(2), FZHDRP(2)
      DATA ENU/1.28E-5/
C
      PBAR = PB-PINF
      PBHEAD = PBAR/(RHO*G)
C
C     GAF OR WETTFD DRAFT CALCULATION
C
C
      DO 5 J=1,2
      N = NSTA(J)
C
      DO 5 K=1,N
      DD = ZS+Z+YY(J,K)*PHI-XX(1,K)*THETA+ETA(J,K)
      DDIN = DD-WATSLP*(XPWVXS-XX(J,K))
      IF (DDIN.LT.BUBHGT) GO TO 1
      IF (VAL(1)-TOLD.LT.DELPNT) GO TO 1
      TOLD = VAL(1)
      WRITE (6,14) XX(J,K),VAL(1),DD
    1 CONTINUE
      DSW(J,K) = (SIGN(1.,DD)+1.)*DD/2.
      IF (DDIN) 2,4,4
    2 IF (DSW(J,K)-PBHEAD) 3,4,4
    3 GAP(J,K) = -DDIN*(1.-(DSW(J,K))/PBHEAD)
      GO TO 5
    4 GAP(J,K) = 0.0
    5 CONTINUE
C
C
C     LEAKAGE AREA
C
      ALSW = 0.0
C
      DO 6 J=1,2
      N = NSTA(J)-1
C
      DO 6 I=1,N
      ALSW = ALSW+(GAP(J,I)+GAP(J,I+1))*DELX/2.
    6 CONTINUE
C
C
C     CROSS-FLOW DRAG ON SIDEWALLS
C
      FYD = 0.0
      FKD = 0.0
      FND = 0.0
```

```
C
      DO 7 I=1,2
      N = NSTA(I)-1
C
      DO 7 J=1,N
      DSWAV(I,J) = (DSW(I,J)+DSW(I,J+1))/2.
      VREL = V+XAVG(J)*R-(ZS-DSWAV(I,J)/2.)*P
      DF(I,J) = -HRHO*CDSW*VREL*ABS(VREL)*DELX*DSWAV(I,J)
      FYD = FYD+DF(I,J)
      FND = FND+DF(I,J)*XAVG(J)
    7 FKD = FKD-(ZS-DSWAV(I,J)/2.)*DF(I,J)
C
C
C     SET UP STERN LIMIT OF FORCE DETERMINATION
C
      XSS = -XS
      GO TO 8
      ENTRY SIDWLM
      XSS = XMI(IX)
    8 IP = 1.+(THETA*RAD-STH)/DTH
      IP = MAXO(MINO(IP,NTH),1)
      IP1 = MINO(IP+1,NTH)
      DTHETA = (IP-1)*DTH+STH
      CIP = (THETA*RAD-DTHETA)/DTH
C
C     CALC REYNOLDS NO. AND DRAG COEFF.
C
      REY = U*XLSW/ENU
      CDT = .427/(ALOG10(REY)-.407)**2.64
C
C     SIDEWALL FORCES, P/S
C
C
      DO 11 J=1,2
      WAREA = 0.0
      N = NSTA(J)-1
      NI = (XSS+XS)*N/XLSW+1.5
C
      DC 9 I=NI,N
      ZOR1 = 1.
      IF (DSWAV(J,I).EQ.0.0) ZOR1=0.0
    9 WAREA = WAREA+DELX*(2.*DSWAV(J,I)+ZOR1*AVBMSW)
C
      FXH(J) = -HRHO*CDT*WAREA*U*U
      PM1 = 2*J-3
      YLSW = PM1*YSW
      DS = Z+ZS+YLSW*PHI
      DSS = DS-XSS*THETA
```

```
      ZOR1 = (SIGN(1.,DSS)+1.)*0.5
      DSS = DSS*ZOR1
      IDSS = 1.5+(DSS-SBB)/DBB
      IDSS = MINO(NBB,IDSS)
      BS = BB(IDSS)
      ZOR1 = (SIGN(1.,DSS)+1.)*0.5
      DSS = DSS*ZOR1
      DRBOW = DSS-(XX(J,N+1)-XSS)*THETA
      IF (DRBOW.LT.0.0) DRBOW=0.0
      A33S = (RHO*PI*BS**2)*0.125
      A22S = (RHO*.4*PI*DSS**2)*0.5
      IF (THETA.LT.0.0) A22S=.4*RHO*PI*DRBOW*DRBOW*0.5
      DSR = DS-(XREF-XS)*THETA
      ID = 1.+(DSR*12.-SDS)/DDS
      ID = MAXO(MINO(ID,NDS),1)
      DDSR = (ID-1)*DDS+SDS
      ID1 = MINO(ID+1,NDS)
      DID = (DSR*12.-DDSR)/DDS
      BCO = ACO(1,ID,IP)
      BCOO = ACOO(1,ID,IP)
      BC2 = AC2(1,ID,IP)
      BC5 = AC5(1,ID,IP)
      BC6 = AC6(1,ID,IP)
      BCO = BCO+DID*(ACO(1,ID1,IP)-BCO)+DIP*(ACO(1,ID,IP1)-BCO+DID*(ACO(
     11,ID1,IP1)-ACO(1,ID,IP1)-ACO(1,ID1,IP)+BCO))
      BCOO = BCOO+DID*(ACOO(1,ID1,IP)-BCOO)+DIP*(ACOO(1,ID,IP1)-BCOO+DID
     1*(ACOO(1,ID1,IP1)-ACOO(1,ID,IP1)-ACOO(1,ID1,IP)+BCOO))
      BC2 = BC2+DID*(AC2(1,ID1,IP)-BC2)+DIP*(AC2(1,ID,IP1)-BC2+DID*(AC2(
     11,ID1,IP1)-AC2(1,ID,IP1)-AC2(1,ID1,IP)+BC2))
      BC5 = BC5+DID*(AC5(1,ID1,IP)-BC5)+DIP*(AC5(1,ID,IP1)-BC5+DID*(AC5(
     11,ID1,IP1)-AC5(1,ID,IP1)-AC5(1,ID1,IP)+BC5))
      BC6 = BC6+DID*(AC6(1,ID1,IP)-BC6)+DIP*(AC6(1,ID,IP1)-BC6+DID*(AC6(
     11,ID1,IP1)-AC6(1,ID,IP1)-AC6(1,ID1,IP)+BC6))
C
C     SHIFT MOMENT CENTER FROM XREF TO C.G.
C
      BCOO = BCOO-(XS-XREF)*BCO
      BC6 = BC6-(XS-XREF)*BC5
C
C     HYDROSTATIC AND HYDRODYNAMIC FORCES
C
      FZH(J) = -G*BCO-U*U*A33S*THETA-U*A33S*W+Q*U*(-BC2+A33S*XSS)-U*A33S
     1*P*YLSW
      FMH(J) = -U*XSS*XSS*A33S*Q+G*BCOO+U*(A33S*XSS+BC2)*(W+U*THETA+YLSW
     1*P)
      FYH(J) = -A22S*U*(V+XSS*R-ZS*P)
      FNH(J) = FYH(J)*XSS-U*((V-ZS*P)*BC5+R*BC6)
C
```

```
C
C     ADD VERTICAL FORCE DUE TO DEADRISE PROJECTION OF LATERAL FORCE
C
      CTNDR = 0.0
      IF (DSS.LE.0.0) GO TO 10
      CTNDR = (BS-BB(1))/DSS
      IF (THETA.LT.0.0) CTNDR=.39391
   10 CONTINUE
      FZHOLD(J) = FZH(J)
      FZHDRP(J) = PM1*FYH(J)*CTNDR*PROMO1
      FZH(J) = FZH(J)+FZHDPP(J)
      IF (IMT.EQ.2) GO TO 11
C
C     CALC OF FORCE ON VENTRAL FINS REMOVED
C
   11 CONTINUE
C
      IF (IMT.EQ.2) GO TO 12
C
C     TOTAL SIDEWALL FORCES AMD MOMENTS
C
      FX = FXH(1)+FXH(2)
      FY = FYH(1)+FYH(2)
      FZ = FZH(1)+FZH(2)
      FK = (FZH(2)-FZH(1))*YSW+FKD-FY*ZS
      FY = FY+FYD
      FM = FMH(1)+FMH(2)+ZS*FX
      FN = FND+FNH(1)+FNH(2)+(FXH(1)-FXH(2))*YSW
C
C     DRAG FORCE ON FINS REMOVED
C
   12 CONTINUE
C
C     ADD ROLL DAMPING DUE TO VERTICAL WAVE GENERATION
C
      DSS = Z+ZS-XSS*THETA
      ZOR1 = (SIGN(1.,DSS)+1.)/2.
      DSS = DSS*ZOR1
      DS = Z+ZS
      DSR = DS-(XREF-XS)*THETA
      ID = 1.+(DSR*12.-SDS)/DDS
      ID = MAX0(MIN0(ID,NDS),1)
      DDSR = (ID-1)*DDS+SDS
      ID1 = MIN0(ID+1,NDS)
      DID = (DSR*12.-DDSR)/DDS
      BC2 = AC2(1,ID,IP)
      BC2 = BC2+DID*(AC2(1,ID1,IP)-BC2)+DIP*(AC2(1,ID,IP1)-BC2+DID*(AC2(
     11,ID1,IP1)-AC2(1,ID,IP1)-AC2(1,ID1,IP)+BC2))
      FKCLD = FK
```

```
      FK = FK-PROMO2*YSW*YSW*BC2*P/PI
      FZH(1) = FZH(1)+PROMO2/2.*YSW*BC2*P/PI
      FZH(2) = FZH(2)-PROMO2/2.*YSW*BC2*P/PI
      IF (PROMO3.EQ.1.0) WRITE (6,15) VAL(1),FZHOLD(1),FZHOLD(2),FZHDRP(
     11),FZHDRP(2),FZH(1),FZH(2),FKOLD,FK
      IF (ISIDWL.NE.ON) RETURN
C
      DO 13 I=1,2
C
      DO 13 J=1,11
      GAP(I,J) = 12.0*GAP(I,J)
   13 DSW(I,J) = 12.0*DSW(I,J)
C
      WRITE (6,16) ((GAP(I,J),J=1,11),I=1,2),((DSW(I,J),J=1,11),I=1,2),F
     1X,FY,FZ,FK,FM,FN
C
C
      RETURN
C
   14 FORMAT (/10X,43HWATER CONTACT WITH TOP OF BUBBLE CHAMBER ATF7.2,14
     1H FT.     TIME =F7.2,19H SEC.     IMMERSION=F7.2,4H FT.)
   15 FORMAT (/2X,'TIME=',1X,E15.4,2X,'OLD VERTICAL FORCES',2(5X,E15.4)/
     1 25X,'VERTICAL DEADRISE FORCES',2(5X,E15.4)/25X,'NEW VERTICAL FORC
     2ES',2(5X,E15.4)/25X,'OLD AND NEW ROLL MOMENTS',2(5X,E15.4)/)
   16 FORMAT (/10X,8HSIDEWALL/25H GAP (FT.) (STERN TO BOW)/14H PORT SIDE
     1WALL/11F10.5/14H STBD SIDEWALL/11F10.5/37H IMMERSION DEPTH (FT.) (
     2STERN TO BOW)/14H PORT SIDEWALL/11F10.5/14H STBD SIDEWALL/11F10.5/
     310X,26HSIDEWALL FX,FY,FZ,FK,FM,FN/6E15.4)
      END

      FUNCTION SHXYAX (X,Z,ANGYAX,PI)
C
      H = SQRT(X*X+Z*Z)
      IF (X.EQ.0.0) GO TO 1
      ARG = Z/X
      ANGOLD = ATAN(ARG)
      IF (ANGOLD.GE.0.0) GO TO 2
      ANGNEW = ANGOLD+PI-ANGYAX
      GO TO 3
    1 ANGNEW = PI*.50-ANGYAX
      GO TO 3
    2 ANGNEW = ANGOLD-ANGYAX
    3 SHXYAX = H*COS(ANGNEW)
C
      RETURN
      END

      SUBROUTINE STNSL
```

```
C
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM
      COMMON /CONST/ PI,RAD,UO
      COMMON /FORSS/ FX,FY,FZ,FK,FM,FN,QL,FMS
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCF,ZCP
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARMIS(10),DFSS(10),TSKIS(10)
     1,ARM2S(10)
      COMMON /KSWTCH/ ITHRST
      COMMON /LEAKER/ ALEAK,CFSS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /SLCPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
     1GS(10)
      COMMON /STSLR/ CPHI,CPHID
      COMMON /VALOLD/ YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      DIMENSION GAP(11), ELSKI(11), ELSKIL(11), AIRLEN(11), CTNSL(6,24)
      DATA ENU,GPS,HINGHT/1.28E-5,.4644,1.875/
      DATA CTNSL/0.0,3.8,7.0,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.
     10,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12
     22.4,15.4,18.3,0.0,5.5,9.4,13.1,16.1,19.2,0.0,5.8,9.9,13.8,17.1,20.6
     33,0.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,1
     41.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,2
     54.1,28.3,0.0,8.2,15.3,22.1,26.3,30.8,0.0,9.6,17.5,24.2,29.7,34.6,0
     66.0,11.9,20.0,25.4,32.3,38.0,0.0,14.0,23.3,30.0,35.8,41.0,0.0,17.5,
     725.5,32.5,39.7,44.5,0.0,21.6,30.0,38.7,42.0,47.0,0.0,24.6,33.7,41.
     80,45.0,48.7,0.0,28.3,38.5,45.0,48.7,48.7,0.0,35.0,45.0,48.7,48.7,4
     98.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,
     $48.7,48.7,48.7,48.7,48.7/
C
      IF (ELMAXS.GT.HINGHT) ELMAXS=HINGHT
C
      DO 1 J=1,11
      GAP(J) = 0.0
      ELSKI(J) = 0.0
```

```
      ELSKIL(J) = 0.0
      AIRLEN(J) = 0.0
    1 CONTINUE
C
C
C     'EFDEP' IS THE EFFECTIVE LIFTING DEPTH OF THE STERN SEAL
C
      EFDEP = 6.0
      MM = EFDEP
      ALSS = 0.0
      FX = 0.0
      FZ = 0.0
      FK = 0.0
      FM = 0.0
      FN = 0.0
      AGAP1 = 0.0
      AGAP2 = 0.0
      AGAPA1 = 0.0
      DELP = PSS-PB
      IF (DELP.LT.0.0) DELP=0.0
      PBAR = PB-PINF
C
C     CALCULATE ELSKI HERE.
C
      SINDIF = SINTH-COSTH*THETA
      COSDIF = COSTH+SINTH*THETA
      X1 = XSS+ZSS*THETA-XLF*SINDIF
      Z1 = (-Z-ZSS+XSS*THETA-ELMAXS*COS(THETA))
C
C     CALCULATE GAP HERE.
C
      N = NSTA(4)
C
      DC 2 K=1,N
      ELSKI(K) = (ETA(4,K)-DETADX(K)*(XX(4,K)-X1)-Z1)+YY(4,K)*PHI-XPWV*W
     1ATSLP
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT
      ELSKIL(K) = ELSKI(K)+GPS
      IF (ELSKIL(K).GT.HINGHT) ELSKIL(K)=HINGHT
      IF (ELSKIL(K).LT.(HINGHT-ELMAXS)) ELSKIL(K)=HINGHT-ELMAXS
      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXS)
      IF (GAP(K).LT.0.0) GAP(K)=0.0
      MM1 = ELSKIL(K)*12.0
      MM2 = MM1+1
      MM3 = MM2+1
      DLINC = ELSKIL(K)*12.0-MM1
      STNSL1 = CTNSL(MM,MM2)
      STNSL2 = CTNSL(MM,MM3)
```

```
      AIRLEN(K) = ((STNSL2-STNSL1)*DLINC+STNSL1)/12.0
    2 CCNTINUE
C
      N = NSTA(4)-1
C
      DO 5 J=1,N
      ELSKIA = (ELSKI(J+1)+ELSKI(J))*0.5
      ELSKLA = (ELSKIL(J+1)+ELSKIL(J))*0.5
      AIRLAV = (AIRLEN(J+1)+AIRLEN(J))*0.5
      AGAP = ELSKLA-ELSKIA
      AGAP1 = AGAP
      IF (AGAP.LT.GPS) AGAP=GPS
      IF (AGAP1.GT.GPS) AGAP1=GPS
      ARM1S(J) = XX(4,J)+ELSKIA*0.5
      ARM2S(J) = ZS-ELSKIA
      DFSS(J) = -DELP*DELYSS*AIRLAV/(GPS/AGAP)**2
      IF (AIRLAV.LE.0.0) GO TO 3
      ARG = .5*RHO*U*U*AIRLAV*DELYSS
      RESKI = U*AIRLAV/ENU
      CDTSKI = .427/(ALOG10(RESKI)-.407)**2.64
      TSKIS(J) = -ARG*CDTSKI
C
C     THE FOLLOWING CARD REMOVES WATER DRAG EFFECTS OF STERN SEAL
C
      TSKIS(J) = 0.0
      GO TO 4
    3 TSKIS(J) = 0.0
    4 CONTINUE
      FX = FX+TSKIS(J)
      FZ = FZ+DFSS(J)
      FK = FK+DFSS(J)*YAVGS(J)
      FM = FM-DFSS(J)*ARM1S(J)+TSKIS(J)*ARM2S(J)
      FN = FN-TSKIS(J)*YAVGS(J)
      ALSS = ALSS+(GAP(J)+GAP(J+1))*DELYSS*0.5
      AGAP2 = AGAP2+AGAP1
      AGAPA1 = AGAP2/J
    5 CONTINUE
C
      ALSS = ALSS+ALEAK*(AGAPA1/GPS)
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)
      QL = CFSS*ALSS*SQFAC*SIGN(1.,PBAR)
      IF (ISTNSL.NE.ON) RETURN
      WRITE (6,6) GAP,AIRLEN,FX,FY,FZ,FK,FM,FN
C
C
      RETURN
C
    6 FORMAT (//12H  STERN SEAL/26H  GAP (FT.) PORT TO STBD. /11E11.3/28
```

```
 1H  AIRLEN(FT.) PORT TO STBD. /11E11.3/10X,23HSTNSL  FX,FY,FZ,FK,FM,SSL
 2FN/6E15.4)                                                       SSL
      END                                                          SSL

      FUNCTION T1 (X)                                              T1
C                                                                  T1
      IF (ABS(X)-.1) 1,1,2                                         T1
    1 T1 = X*(1.-X*X/10.0)/3.                                      T1
      RETURN                                                       T1
    2 T1 = (SIN(X)-X*COS(X))/(X*X)                                 T1
      RETURN                                                       T1
      END                                                          T1

      FUNCTION T2 (X)                                              T2
C                                                                  T2
      IF (ABS(X)-.1) 1,1,2                                         T2
    1 T2 = 1.-X*X/6.                                               T2
      RETURN                                                       T2
    2 T2 = SIN(X)/X                                                T2
      RETURN                                                       T2
      END                                                          T2

      INTEGER ON                                                   WAVS
      COMMON /BMCO/ IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY WAVS
      COMMON /CONST/ PI,RAD,UO                                     WAVS
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,WAVS
     110),XCP,ZCP                                                  WAVS
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)WAVS
     1,TSKIB(10)                                                   WAVS
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)WAVS
     1,ARM2S(10)                                                   WAVS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS, AMWAVS
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HPHO                    WAVS
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)     WAVS
      COMMON /PLENUM/ XLBW,XBBW,ABW,BUPHGT,DVWDOT                  WAVS
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IWAVS
     1RUD,IPROP,IAEROD,IRHS                                        WAVS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7 WAVS
      COMMON /RISER/ AMPTC                                         WAVS
      COMMON /SIDE/ FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWAVS
     1W,VAREA,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ,AVRMSW,DELX,VTC    WAVS
      COMMON /VARBLE/ VAL(40)                                      WAVS
      COMMON /WAVE/ ETA(4,11),AW(20),OMEGA(20),DVOLW,NWAVE,BETA,FXWAV,FYWAVS
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBWAVS
     2BAR                                                          WAVS
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,ACWAVS
     11(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),AC5(20,5,7),AC6(20,5WAVS
     2,7),AC7(20,5,7),AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),AS1(20,5,7),AWAVS
```

```
     3S2(20,5,7),AS3(20,5,7),AS4(20,5,7),AS5(20,5,7),AS6(20,5,7),AS7(20,
     45,7),ASO(20,5,7),ASOO(20,5,7),AS8(20,5,7),BB(36),XREF,RX
      DIMENSION WCO(2), WCOO(2), WC1(2), WC2(2), WC3(2), WC4(2), WC5(2),
     1 WC6(2), WC7(2), WC8(2)
      DIMENSICN WSO(2), WSOO(2), WS1(2), WS2(2), WS3(2), WS4(2), WS5(2),
     1 WS6(2), WS7(2), WS8(2)
      EQUIVALENCE (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAL(5),P), (VAL(6
     1),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAL(10),Z), (VAL(
     211),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI), (VAL(24),PB)
      EQUIVALENCE (VAL(16),ETACG)
C
      IF (NWAVE.EQ.0) RETURN
C
C     CALCULATION OF SHIFT OF XCPO
C
      XCPU = XCP+0.001975*(U*0.5921-30.0)**2-0.974
      XCPC = SHXYAX(XCPU,ZCP,THETA,PI)
      GAMMA = BETA-PSI
      SIGAM = SIN(GAMMA)
      COGAM = COS(GAMMA)
      FO = -X*COSBET-Y*SINBET
      DVOLW = 0.0
      ETACG = 0.0
      N = NSTA(3)
C
      DO 1 J=1,N
      DETABX(J) = 0.0
    1 CONTINUE
C
      N = NSTA(4)
C
      DO 2 J=1,N
      DETADX(J) = 0.0
    2 CONTINUE
C
C
      DO 3 J=1,4
      N = NSTA(J)
C
      DO 3 K=1,N
    3 ETA(J,K) = 0.0
C
C
      DO 4 J=1,2
      FXW(J) = 0.0
      FYW(J) = 0.0
      FZW(J) = 0.0
      FKW(J) = 0.0
```

```
      FMW(J) = 0.0
      FNW(J) = 0.0
    4 CCNTINUE
C
      XSS = -XS
      IF (IMT.EQ.2) XSS = XMI(IX)
      IP = 1+(THEBAR*RAD-STH)/DTH
      IP = MAXO(MINO(IP,NTH),1)
      IP1 = MINO(IP+1,NTH)
      DTHETA = (IP-1)*DTH+STH
      DIP = (THETA*RAD-DTHETA)/DTH
C     TIME RISE FACTOR FOR WAVE AMPLITUDE
      AMPFAC = 1.-EXP(-TIME/AMPTC)
C
      DO 11 I=1,NWAVE
      OM1 = CMEGA(I)
      OM2 = CM1*CM1
      XWK = CM2/G
      AA = AW(I)*AMPFAC
      FT = OM1*TIME+XWK*FO
      AL = XWK*COGAM
      IAA = 1+(ABS(AL)-SAL)/DAL
      IAA = MAXO(MINO(IAA,NAL),1)
      IAA1 = MINO(IAA+1,NAL)
      DAA = (IAA-1)*DAL+SAL
      DIA = (ABS(AL)-DAA)/DAL
      SALP = SIGN(1.,AL)
C
C     WAVE FORCES AND MOMENTS ON THE SIDEWALLS
C
C
      DO 7 J=1,2
      YLSW = (2*J-3)*YSW
      WE = FT+XWK*SIGAM*YLSW
      ST = SIN(WE)
      CT = COS(WE)
      DS = ZBAR+ZS+YLSW*PHIBAR
      DSR = DS-(XREF-XS)*THEBAR
      ID = 1.+(DSR*12.-SDS)/DDS
      ID = MAXO(MINO(ID,NDS),1)
      DDSR = (ID-1)*DDS+SDS
      CID = (DSR*12.-DDSR)/DDS
      ID1 = MINO(ID+1,NDS)
      DSS = DS-XSS*THEBAR
      ZOR1 = (SIGN(1.,DSS)+1.)*0.5
      DSS = DSS*ZOR1
      IDSS = 1.5+(DSS-SBB)/DBB
      IDSS = MINO(NBB,IDSS)
```

```
      BS = BB(IDSS)
      CK = CCS(XWK*COGAM*XSS)
      A33S = (RHO*PI*BS*BS)*0.125
      SK = SIN(XWK*COGAM*XSS)
      A22S = (RHO*.4*PI*DSS*DSS)*0.5
      A42S = 0.0
C
C     INTERPCLATION OF WAVE TABLES
C
      K = 1
      L = IAA
    5 CONTINUE
      BCO = ACO(L,ID,IP)
      BC00 = AC00(L,ID,IP)
      BC1 = AC1(L,ID,IP)
      BC2 = AC2(L,ID,IP)
      BC3 = AC3(L,ID,IP)
      BC4 = AC4(L,ID,IP)
      BC5 = AC5(L,ID,IP)
      BC6 = AC6(L,ID,IP)
      BC7 = AC7(L,ID,IP)
      BC8 = AC8(L,ID,IP)
      BSO = ASO(L,ID,IP)
      BS00 = AS00(L,ID,IP)
      BS1 = AS1(L,ID,IP)
      BS2 = AS2(L,ID,IP)
      BS3 = AS3(L,ID,IP)
      BS4 = AS4(L,ID,IP)
      BS5 = AS5(L,ID,IP)
      BS6 = AS6(L,ID,IP)
      BS7 = AS7(L,ID,IP)
      BS8 = AS8(L,ID,IP)
      WCO(K) = BCO+DID*(ACO(L,ID1,IP)-BCO)+DIP*(ACO(L,ID,IP1)-BCO+DID*(A
     1CO(L,ID1,IP1)-ACO(L,ID,IP1)-ACO(L,ID1,IP)+BCO))
      WC00(K) = BC00+DID*(AC00(L,ID1,IP)-BC00)+DIP*(AC00(L,ID,IP1)-BC00+
     1DID*(AC00(L,ID1,IP1)-AC00(L,ID,IP1)-AC00(L,ID1,IP)+BC00))
      WC1(K) = BC1+DID*(AC1(L,ID1,IP)-BC1)+DIP*(AC1(L,ID,IP1)-BC1+DID*(A
     1C1(L,ID1,IP1)-AC1(L,ID,IP1)-AC1(L,ID1,IP)+BC1))
      WC2(K) = BC2+DID*(AC2(L,ID1,IP)-BC2)+DIP*(AC2(L,ID,IP1)-BC2+DID*(A
     1C2(L,ID1,IP1)-AC2(L,ID,IP1)-AC2(L,ID1,IP)+BC2))
      WC3(K) = BC3+DID*(AC3(L,ID1,IP)-BC3)+DIP*(AC3(L,ID,IP1)-BC3+DID*(A
     1C3(L,ID1,IP1)-AC3(L,ID,IP1)-AC3(L,ID1,IP)+BC3))
      WC4(K) = BC4+DID*(AC4(L,ID1,IP)-BC4)+DIP*(AC4(L,ID,IP1)-BC4+DID*(A
     1C4(L,ID1,IP1)-AC4(L,ID,IP1)-AC4(L,ID1,IP)+BC4))
      WC5(K) = BC5+DID*(AC5(L,ID1,IP)-BC5)+DIP*(AC5(L,ID,IP1)-BC5+DID*(A
     1C5(L,ID1,IP1)-AC5(L,ID,IP1)-AC5(L,ID1,IP)+BC5))
      WC6(K) = BC6+DID*(AC6(L,ID1,IP)-BC6)+DIP*(AC6(L,ID,IP1)-BC6+DID*(A
     1C6(L,ID1,IP1)-AC6(L,ID,IP1)-AC6(L,ID1,IP)+BC6))
```

```
      WC7(K) = BC7+DID*(AC7(L,ID1,IP)-BC7)+DIP*(AC7(L,ID,IP1)-BC7+DID*(AWAVS1710
     1C7(L,ID1,IP1)-AC7(L,ID,IP1)-AC7(L,ID1,IP)+BC7))                   WAVS1720
      WC8(K) = BC8+DID*(AC8(L,ID1,IP)-BC8)+DIP*(AC8(L,ID,IP1)-BC8+DID*(AWAVS1730
     1C8(L,ID1,IP1)-AC8(L,ID,IP1)-AC8(L,ID1,IP)+BC8))                   WAVS1740
      WS0(K) = BS0+DID*(AS0(L,ID1,IP)-BS0)+DIP*(AS0(L,ID,IP1)-BS0+DID*(AWAVS1750
     1S0(L,ID1,IP1)-AS0(L,ID,IP1)-AS0(L,ID1,IP)+BS0))                   WAVS1760
      WS00(K) = BS00+DID*(AS00(L,ID1,IP)-BS00)+DIP*(AS00(L,ID,IP1)-BS00+WAVS1770
     1DID*(AS00(L,ID1,IP1)-AS00(L,ID,IP1)-AS00(L,ID1,IP)+BS00))         WAVS1780
      WS1(K) = BS1+DID*(AS1(L,ID1,IP)-BS1)+DIP*(AS1(L,ID,IP1)-BS1+DID*(AWAVS1790
     1S1(L,ID1,IP1)-AS1(L,ID,IP1)-AS1(L,ID1,IP)+BS1))                   WAVS1800
      WS2(K) = BS2+DID*(AS2(L,ID1,IP)-BS2)+DIP*(AS2(L,ID,IP1)-BS2+DID*(AWAVS1810
     1S2(L,ID1,IP1)-AS2(L,ID,IP1)-AS2(L,ID1,IP)+BS2))                   WAVS1820
      WS3(K) = BS3+DID*(AS3(L,ID1,IP)-BS3)+DIP*(AS3(L,ID,IP1)-BS3+DID*(AWAVS1830
     1S3(L,ID1,IP1)-AS3(L,ID,IP1)-AS3(L,ID1,IP)+BS3))                   WAVS1840
      WS4(K) = BS4+DID*(AS4(L,ID1,IP)-BS4)+DIP*(AS4(L,ID,IP1)-BS4+DID*(AWAVS1850
     1S4(L,ID1,IP1)-AS4(L,ID,IP1)-AS4(L,ID1,IP)+BS4))                   WAVS1860
      WS5(K) = BS5+DID*(AS5(L,ID1,IP)-BS5)+DIP*(AS5(L,ID,IP1)-BS5+DID*(AWAVS1870
     1S5(L,ID1,IP1)-AS5(L,ID,IP1)-AS5(L,ID1,IP)+BS5))                   WAVS1880
      WS6(K) = BS6+DID*(AS6(L,ID1,IP)-BS6)+DIP*(AS6(L,ID,IP1)-BS6+DID*(AWAVS1890
     1S6(L,ID1,IP1)-AS6(L,ID,IP1)-AS6(L,ID1,IP)+BS6))                   WAVS1900
      WS7(K) = BS7+DID*(AS7(L,ID1,IP)-BS7)+DIP*(AS7(L,ID,IP1)-BS7+DID*(AWAVS1910
     1S7(L,ID1,IP1)-AS7(L,ID,IP1)-AS7(L,ID1,IP)+BS7))                   WAVS1920
      WS8(K) = BS8+DID*(AS8(L,ID1,IP)-BS8)+DIP*(AS8(L,ID,IP1)-BS8+DID*(AWAVS1930
     1S8(L,ID1,IP1)-AS8(L,ID,IP1)-AS8(L,ID1,IP)+BS8))                   WAVS1940
      IF (K.EQ.2) GO TO 6                                               WAVS1950
      K = 2                                                             WAVS1960
      L = IAA1                                                          WAVS1970
      GO TO 5                                                           WAVS1980
    6 BC0 = WC0(1)+DIA*(WC0(2)-WC0(1))                                  WAVS1990
      BC00 = WC00(1)+DIA*(WC00(2)-WC00(1))                              WAVS2000
      BC1 = WC1(1)+DIA*(WC1(2)-WC1(1))                                  WAVS2010
      BC2 = WC2(1)+DIA*(WC2(2)-WC2(1))                                  WAVS2020
      BC3 = WC3(1)+DIA*(WC3(2)-WC3(1))                                  WAVS2030
      BC4 = WC4(1)+DIA*(WC4(2)-WC4(1))                                  WAVS2040
      BC5 = WC5(1)+DIA*(WC5(2)-WC5(1))                                  WAVS2050
      BC6 = WC6(1)+DIA*(WC6(2)-WC6(1))                                  WAVS2060
      BC7 = WC7(1)+DIA*(WC7(2)-WC7(1))                                  WAVS2070
      BC8 = WC8(1)+DIA*(WC8(2)-WC8(1))                                  WAVS2080
      BS0 = (WS0(1)+DIA*(WS0(2)-WS0(1)))*SALP                           WAVS2090
      BS00 = (WS00(1)+DIA*(WS00(2)-WS00(1)))*SALP                       WAVS2100
      BS1 = (WS1(1)+DIA*(WS1(2)-WS1(1)))*SALP                           WAVS2110
      BS2 = (WS2(1)+DIA*(WS2(2)-WS2(1)))*SALP                           WAVS2120
      BS3 = (WS3(1)+DIA*(WS3(2)-WS3(1)))*SALP                           WAVS2130
      BS4 = (WS4(1)+DIA*(WS4(2)-WS4(1)))*SALP                           WAVS2140
      BS5 = (WS5(1)+DIA*(WS5(2)-WS5(1)))*SALP                           WAVS2150
      BS6 = (WS6(1)+DIA*(WS6(2)-WS6(1)))*SALP                           WAVS2160
      BS7 = (WS7(1)+DIA*(WS7(2)-WS7(1)))*SALP                           WAVS2170
      BS8 = (WS8(1)+DIA*(WS8(2)-WS8(1)))*SALP                           WAVS2180
```

```
C
C     SHIFT MCMENT CENTER FROM XREF TO C.G.
C
      BCOO = BCOO-(XS-XREF)*BCO
      BC3 = BC3-(XS-XREF)*BC1
      BC4 = BC4-(XS-XREF)*BC2
      BC6 = BC6-(XS-XREF)*BC5
      BSOO = BSOO-(XS-XREF)*BSO
      BS3 = BS3-(XS-XREF)*BS1
      BS4 = BS4-(XS-XREF)*BS2
      BS6 = BS6-(XS-XREF)*BS5
C
C     CALCULATE WAVE FORCES AND MOMENTS
C
      FZC = BS1-XWK*G*(BS2+BSO)-U*OM1*(-A33S*CK-AL*BS2)
      FZS = BC1-XWK*G*(BC2+BCO)+U*OM1*(-A33S*SK+AL*BC2)
      FMC = BS3-XWK*G*(BS4+BSOO)-U*OM1*(-A33S*XSS*CK-BC2-AL*BS4)
      FMS = BC3-XWK*G*(BC4+BCOO)+U*OM1*(-A33S*XSS*SK-BS2+AL*BC4)
      FYC = XWK*G*(BC5+BCO)-U*OM1*(-A22S*SK+AL*BC5)
      FYS = -XWK*G*(BS5+BSO)-U*OM1*(-A22S*CK-AL*BS5)
      FNC = XWK*G*(BC6+BCOO)-U*OM1*(-A22S*XSS*SK-BS5+AL*BC6)
      FNS = -XWK*G*(BS6+BSOO)-U*OM1*(-A22S*XSS*CK-BC5-AL*BS6)
      FKC = XWK*G*(BC7-BC8)+U*OM1*(-A42S*SK+AL*BC8)
      FKS = -XWK*G*(BS7-BS8)+U*OM1*(-A42S*CK-AL*BS8)
      FZW(J) = FZW(J)-AA*(FZC*CT+FZS*ST)
      FMW(J) = FMW(J)+AA*(FMC*CT+FMS*ST)
      FYW(J) = FYW(J)-AA*(FYC*CT+FYS*ST)*SIGAM
      FNW(J) = FNW(J)-AA*(FNC*CT+FNS*ST)*SIGAM
      FKW(J) = FKW(J)-AA*(FKC*CT+FKS*ST)*SIGAM
      FXW(J) = FXW(J)-2.*AA*RHO*G*BS*DSS*SK*CT
    7 CONTINUE
C
      IF (IMT.EQ.2) GO TO 11
C
C     WAVE ELEVATION AROUND THE SIDEWALLS AND SEALS
C
C
      DO 8 J=1,4
      N = NSTA(J)
C
      DO 8 K=1,N
      ETA(J,K) = ETA(J,K)+SIN(XWK*(-XX(J,K)*COGAM-YY(J,K)*SIGAM)+FT)*AA
    8 CONTINUE
C
      ETACG = ETACG+AA*SIN(FT)
      N = NSTA(3)
C
      DO 9 J=1,N
```

```
      ARG =  AA*COS(XWK*(-XX(3,J)*COGAM)+FT)
      DETABX(J) = DETABX(J)-XWK*COGAM*ARG
    9 CONTINUE
C
      N = NSTA(4)
C
      DO 10  J=1,N
      ARG =  AA*COS(XWK*(-XX(4,J)*COGAM)+FT)
      DETADX(J) = DETADX(J)-XWK*COGAM*ARG
   10 CONTINUE
C
C
C     WAVE  PUMPING
C
      X1  =  XWK*XLBW*COGAM*0.5
      X2  =  XWK*XBBW*SIGAM*0.5
      FTT  =  FT-XWK*XCPC*COGAM
      DVOLW  =  DVOLW+AA*ABW*T2(X1)*T2(X2)*SIN(FTT)
   11 CONTINUE
C
      IF (TIME.EQ.0.0) GO TO 12
      DVWDOT  =  (DVOLW-DVOLWO)/(TIME-TIMEO)
   12 DVOLWO  =  DVOLW
      TIMEO  =  TIME
      IF (IMT.EQ.2) RETURN
C
C     TOTAL  WAVE  FORCES  AND  MOMENTS
C
      FXWAV  =  FXW(1)+FXW(2)
      FYWAV  =  FYW(1)+FYW(2)
      FZWAV  =  FZW(1)+FZW(2)
      FKWAV  =  FKW(1)+FKW(2)+(FZW(2)-FZW(1))*YSW+FYWAV*ZBAR
      FMWAV  =  FMW(1)+FMW(2)-FXWAV*ZBAR
      FNWAV  =  FNW(1)+FNW(2)+(FXW(1)-FXW(2))*YSW
      IF (IWAVES.NE.ON)  RETURN
      WRITE (6,13)  ((ETA(I,J),J=1,11),I=1,4),ETACG,DVOLW,FXWAV,FYWAV,FZW
     1AV,FKWAV,FMWAV,FNWAV
C
C
      RETURN
C
   13 FORMAT  (/10X,5HWAVES/63H WAVE  ELEVATIONS  AT  CRAFT  STATIONS  RELATIV
     1E TO CALM  WATER  (FT.)/14H  PORT  SIDEWALL/11F10.5/14H  STBD  SIDEWALL/
     211F10.5/9H BOW  SEAL/11F10.5/11H  STERN  SEAL/11F10.5/25H  WAVE  ELEVAT
     3ICN  AT  C.G.  =F10.5,10X,43HPLENUM  VOLUME  LOST  DUE  TO  WAVES  (CU.  FT.
     4) =F15.5/10X,23HWAVES  FX,FY,FZ,FK,FM,FN/6E15.4)
      END
```

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